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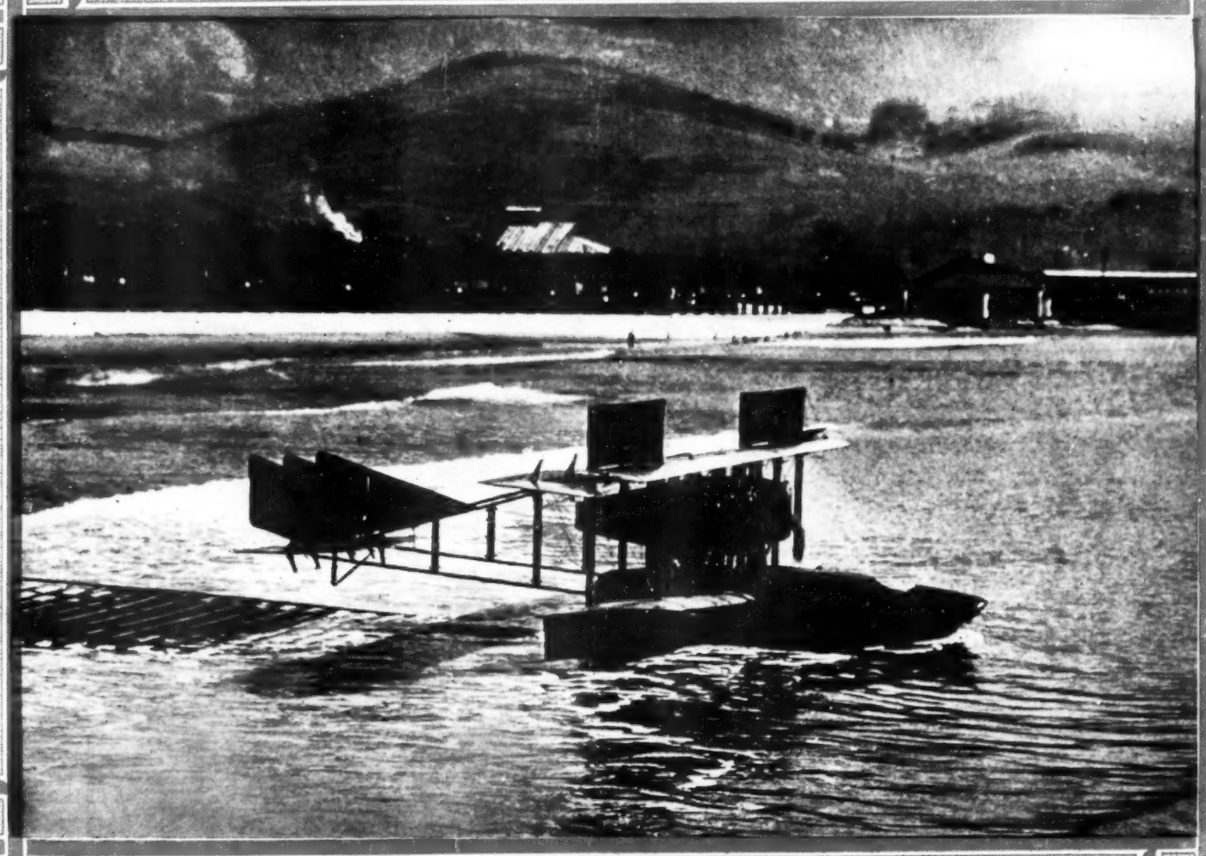

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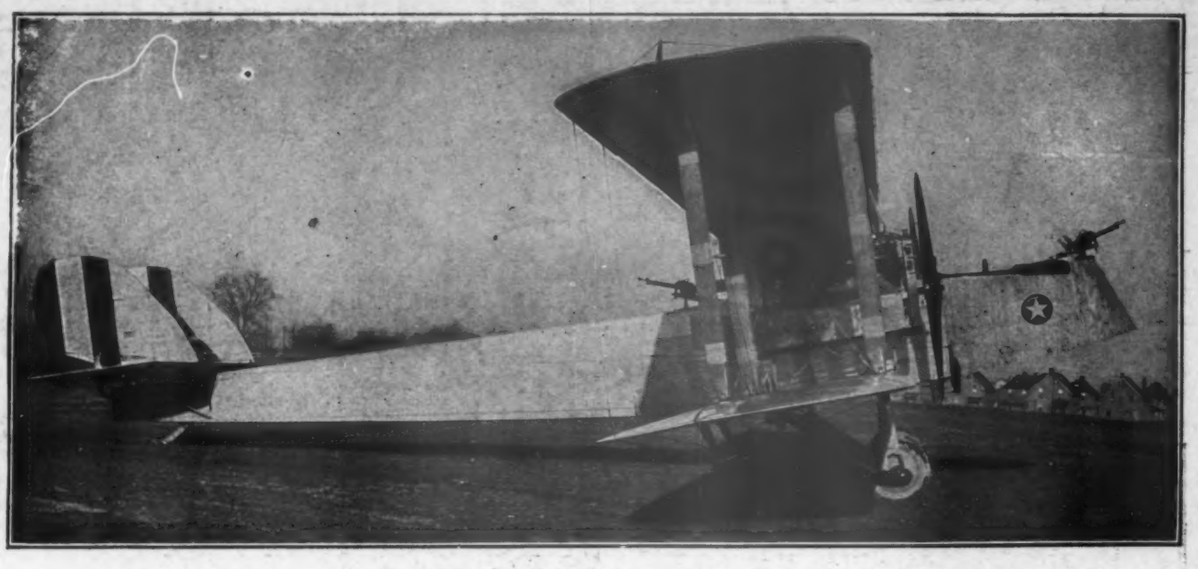

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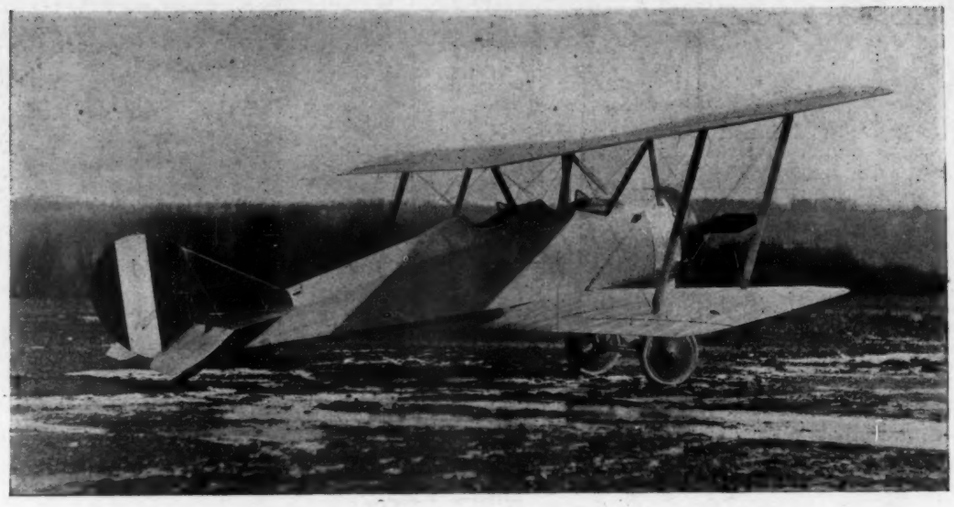

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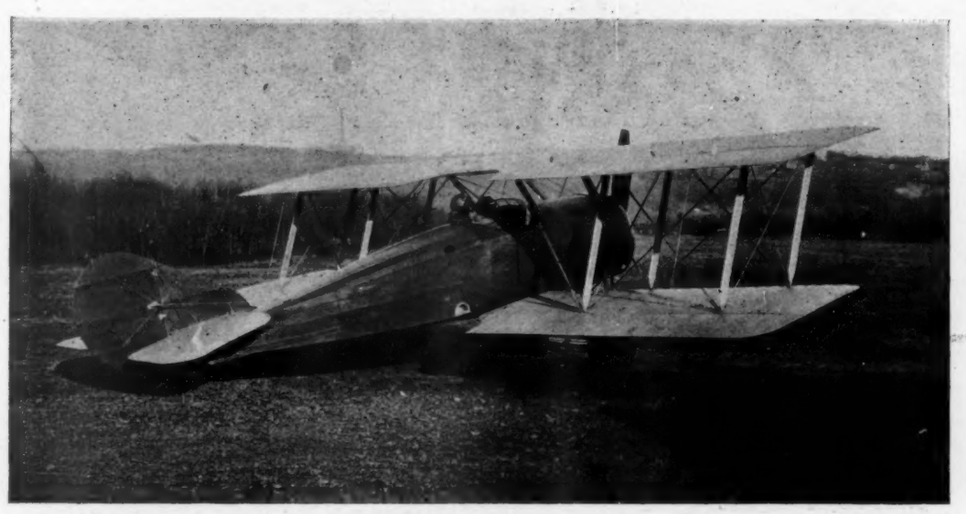

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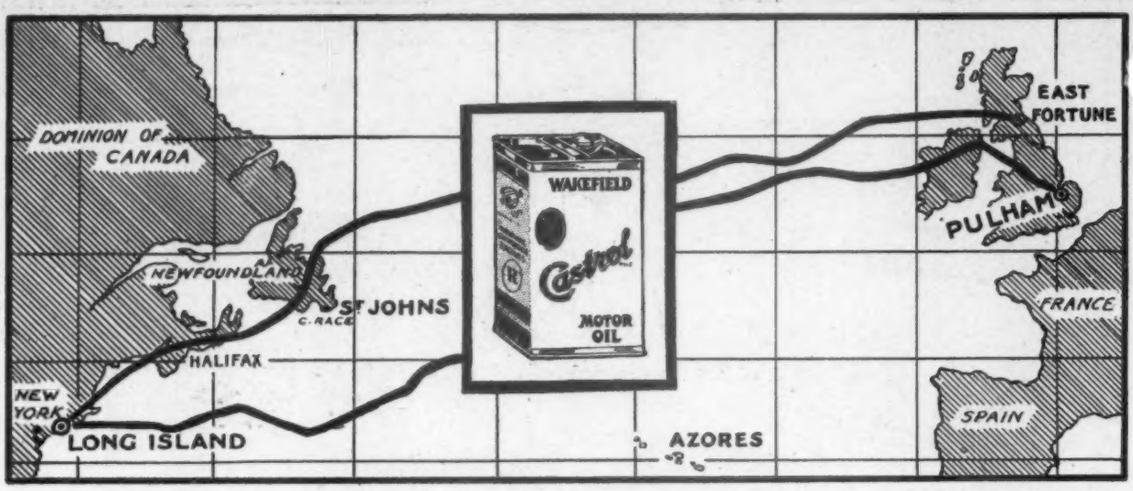

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VOL. VII. NO. 2

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Vol. VII | August 15, 1919 | No. 2

THE bill providing for the amalgamation of the Air Services and for the creation of an air department in the form of an executive agency of the Government, which Senator Harry S. New has brought before Congress, is by far the most comprehensive and well thought out measure that has been proposed with a view to further American aeronautics.

The field of action assigned to the proposed air department is sufficiently ample to provide for any emergency that might come up in connection with the maintenance and up-to-date development of our air forces and the creation of a merchant air force, with the necessary air ports, supply depots, etc. In the words of the New bill, the air department would be " charged with all matters pertaining to aeronautics for the Army and Navy, Post Office Department, Coast Guard, or any other department of Government in times of peace and war, for the improvement and development of the science of aeronautics as may be deemed desirable in the public interest, for the purpose of extending commerce, and for such other utilization as may work to the betterment of the country."

The one great objection which is often made against an independent air force, namely, that the assignment of aeronautical units for tactical employment with the Army and the Navy on the basis of cooperation, that is, without effectual control on the part of the military and naval commanders concerned, would lead to inefficiency is answered in the New bill with a provision to the effect that " the tactical employment of all such units while so assigned shall be under the exclusive control of appropriate military and naval commanders." Hence this objection falls to the ground.

From the viewpoint of commercial aeronautics the creation of a separate air department commends itself with particular forcefulness. The conviction is daily gaining ground that aerial transport services will not come into being until what the French call the " infrastructure "—that is, air routes provided with suitable landing grounds and properly marked for day and night flying—are organized. An organization of this sort is an undertaking of such magnitude that it surpasses the powers of the aircraft industry. A promising beginning has already been made by various cities with the establishment of municipal aerodromes, but it seems that this work should be supervised by the Government so as to insure certain safety requirements and general coordination. An air department would be the proper agency for this kind of work and it should be within its powers to also create a federal air code and thus prevent the threatened individual air legislation by forty-eight states, which would kill aerial transportation in its infancy.

Still another field of activity where an air department could exert healthy influence would be in the licensing, registering and inspecting of aircraft, and the licensing of pilots—which again should be a federal prerogative. The experience of State automobile legislation should be a sufficient warning in this respect.

Finally, not the least important duty of an air department should be the creation of a central aeronautical establishment where aircraft would be tested, both statically and in full flight, before being given a license to carry passengers, and general research and development work would be conducted with respect to aerodynamics and materials of construction.

It may be seen what an immense field of activity awaits a government agency that would have within its attributes the centralization, control and development of aeronautics in all of its applications.

Snow Skids

An important problem which confronts the designer of transport airplanes is the provision for a landing gear which will permit safe get-away and landing on snow-covered fields.

Since it is impossible to know whether an open or a snow-covered field awaits the pilot, the ordinary land chassis must remain intact, and moreover, its ordinary action must not be impeded by the snow skids. They must be high enough about the wheel base not to touch the ground in ordinary landing or get-away.

The action of a skid on landing is in some ways analogous to that of a pontoon. In yielding water the pontoon has some provision of a V-shaped bottom to minimize the first initial shock; so must the skid. When the V has sunk in, the skid must provide a broad bearing surface so that the pressure is not too great, as otherwise immediate stoppage and terrific stresses will be set up. The skid must be long enough and shaped in such a manner that there is no tendency to tilt over.

On get-away similar conditions have to be fulfilled. Moreover, the skid cannot merely be a flat surface. It has to be a box-like structure, with sufficient strength to stand stresses, even though it has not to provide the buoyancy of a water-borne machine.

These and other points offer a fruitful problem for the designer, and usage in the field will soon indicate defects and their remedies.

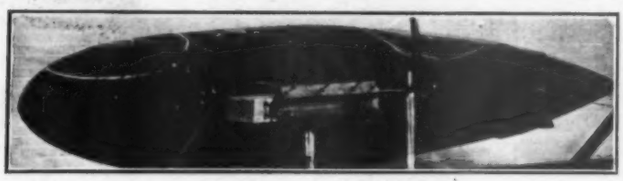
Airship Engineering Progress in the United States

By J. C. Hunsaker, Eng. D.

Commander, Construction Corps, U. S. Navy

Lighter-than-air engineering is a very recent development in the United States, and was not really taken up seriously until December of 1916, when the possibility of the United States becoming involved in submarine warfare began to be feared. The Navy Department had always had a mild interest in airships or dirigibles, and placed a contract in 1915 with a firm which had got hold of a German engineer, a German mechanic and an Austrian airship pilot. This contract called for a training ship of very moderate performance, but it was not delivered until two years later, and was so much overweight and otherwise so unreliable that after a few short flights was broken up as useless. This experience was discouraging, as it was hoped from experience with this ship to get some idea of where the Navy ought to use airships.

However, reports began to drift in of the use by the British Navy of small airships for anti-submarine work, coast patrol and dropping depth bombs. In December, 1916, the Department asked the Bureau of Construction and Repair to design an airship for coast patrol and training work. The characteristics were: speed, 45 m.p.h.; endurance, 12 hr., at 35 m.p.h.; radio for 150 miles; crew of three; provision for alighting on the water.



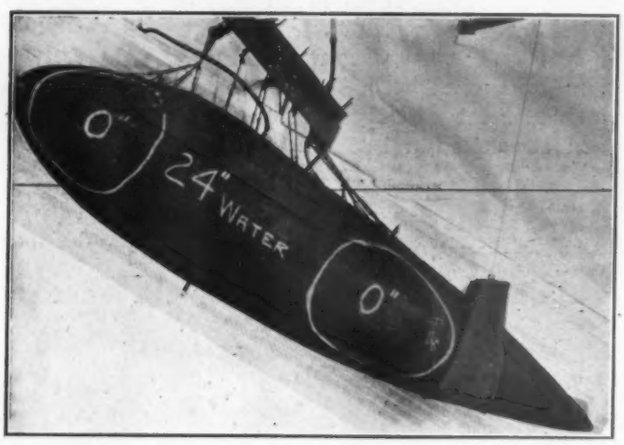


FIG. 1. WATER MODEL OF B CLASS INCLINED 30 DEG., BALLONETS EMPTY

At this time, barring the concern with the German talent, which had built the first rather unfortunate ship, there was no experience in modern airship construction in the country to draw on either for design or for knowledge of the special materials needed.

As the United States still preserved diplomatic relations with Germany, no detailed information from abroad could be secured legitimately.

Development of B Class

To meet the problem, a design was started which was later designated type B. The only engines available having any fair claim to reliability were the 100 b.hp. Curtiss 8-cylinder and the 100 b.hp. Hall-Scott 4-cylinder types. Calculations based on the speed required from this horsepower available and the load to be carried fixed the envelope volume, which was to be a minimum consistent with the characteristics demanded.

Lacking experience, dependence had to be placed on theoretical and experimental investigations. The literature of the art was assembled from the Library of Congress and the Smithsonian Institution, and a deliberate attempt made to read it all. It looked like a very imposing collection, but boiled down there appeared to be little or no practical information. The theory of ballooning was very complete, but it appeared that the theory of airship design had been developed under governmental control in France and Germany, and the greater part had been kept confidential. For details of construction we had the benefit of an inspection of airships made in 1913 in France, England and Germany, and a good deal of information had been collected in spite of the restrictions. However, such information was now four years old.

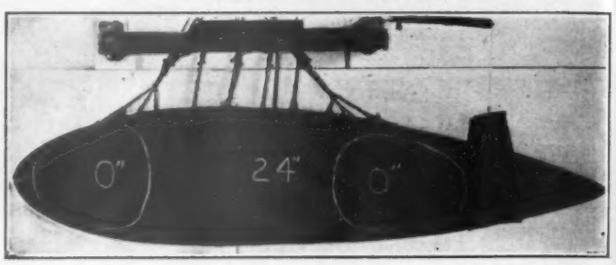


FIG. 2. WATER MODEL OF B CLASS, LEVEL TRIM, BALLONETS EMPTY

To determine a form of envelope of low resistance, a series of models was run in the bureau's wind tunnel and the best selected. The sizes of fin and control surfaces were also determined from wind tunnel tests. We had no practical design rules to follow, and it appeared that a speed of 45 miles per hour for a small airship was so high that difficulties in steering might be anticipated. Accordingly, very careful experimental and theoretical studies were made to make sure. The results on the trials showed that the calculations gave ample stability, and after the pilots had become more experienced it was found possible to cut down the vertical fin surface.

The design of the car presented no difficulties, as we could follow airplane practice, using a standard airplane power plant.

To connect the car to the envelope or gas bag was a different story, however. This is the most delicate part of the design and the point where we were most ignorant. The non-rigid airship keeps its form against the pressure of the air because it is held out full and taut by inner gas pressure. It now was necessary to suspend the car containing all the heavy weights from the fabrics of this gas bag in such a manner as not to deform the bag or put undue local stresses in any part of it. The calculations involved in the design had to be devised from general naval architectural principles, but were not very satisfactory on account of the indeterminate nature of the distribution of load between the various suspension cables. It was desired to use the lightest fabric that could be considered safe, but the envelope must remain fair and stiff, with no more than one inch of water pressure.

The loads were arranged in what appeared a reasonable manner, and the curves of bending moment and shearing force drawn, considering the envelope as a beam. The calculation made was identical with that used in computing the longitudinal strength of vessels, and need not be described further.

To verify the calculated strength of envelope fabric and the internal pressure necessary to preserve fair form under the influence of the suspension loads and the forces to be expected on fins and rudders, a water model experiment was made.

The theory of this test was given by Haas and Dietzius in "Formänderungen der Hülle von Prall Luftschiffe." It is there shown that a one-thirtieth scale model of the airship if made of the fabric it is intended to use, and filled with water instead of gas, will, if suspended in an inverted position, behave statically exactly like the full size ship. That is to say, the stresses and deformations of the envelope will be the same. Tests were made at different pressures and at different trims to make sure that when diving or climbing nothing abnormal would happen. The static balance and control were also studied by inflating the ballonets with air under different conditions.

The calculations appeared to be verified nearly enough and the design was proceeded with. We had no means of knowing what factors of safety to use, in spite of a knowledge of the

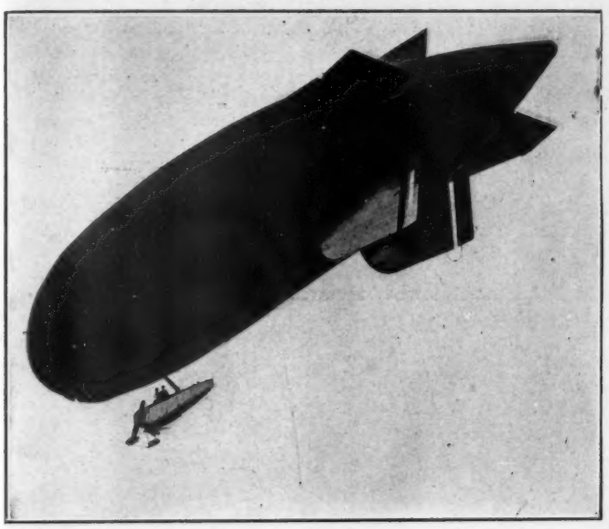


FIG. 3. B CLASS AIRSHIP WITH ORIGINAL DOUBLE FINS

stresses. A factor of safety is a factor of experience, and we had no experience to go on. However, theory was again resorted to and the worst possible conditions in service investigated. Based on such study, a factor of 9 under normal conditions appeared reasonable and was adopted. Curiously enough, we learned later that this is the usual French practice.

The characteristics of the design were as follows:

Length		160 ft.
Diameter		31.5 ft.
Height		50 ft.
Power of main engine		100 hp.
Power of blower engine		2 hp.
Maximum speed		45 mi. per hr.
Cruising speed		35 mi. per hr.
Endurance at 45 miles		10 hr.
Endurance at 35 miles		16 hr.
Gasoline capacity		100 gal.
Ballonet volume		19,250 cu. ft.
Envelope volume		77,000 cu. ft.
Gross lift at .068 lb. per cu. ft		5,275 lb.
Weight empty		3,256 lb.
Instruments, etc	100	
Blower outfit	100	
Radio outfit	250	
Lighting set	15	
2 men	320	
Fuel and oil	633	
Ballast	290	
Margin	311	
Useful load, 38 per cent. or		2,019 lb.

The 1917 Program

The plans were approved by the Secretary of the Navy Jan. 27, 1917, but instead of authorizing the construction of one or two units as an experiment to work out the design, he ordered sixteen airships to be produced as rapidly as possible. This came as a thunderbolt, and it seemed at first impossible of execution. It was impossible to allow six months to build an experimental ship, develop the proper gas tight fabric needed, correct defects in design and then instruct contractors in the manufacture.

The Chief Constructor, therefore, decided to go ahead with the construction regardless of the unproved nature of the design, and on Feb. 6, 1917, sent copies of the plans and specifications to five firms which had offered their facilities to the department for war work and which he considered to be in a position to help. Representatives of these five firms met with the Chief Constructor on Feb. 12 to discuss ways and means for getting the sixteen ships built quickly.

The five firms requested to undertake the work were the Curtiss Aeroplane & Motor Corp., the Connecticut Aircraft Co., and the three great rubber manufacturers—Goodyear, Goodrich and U. S. Rubber. The conference resembled a patriotic meeting rather than a gathering of prospective gov-

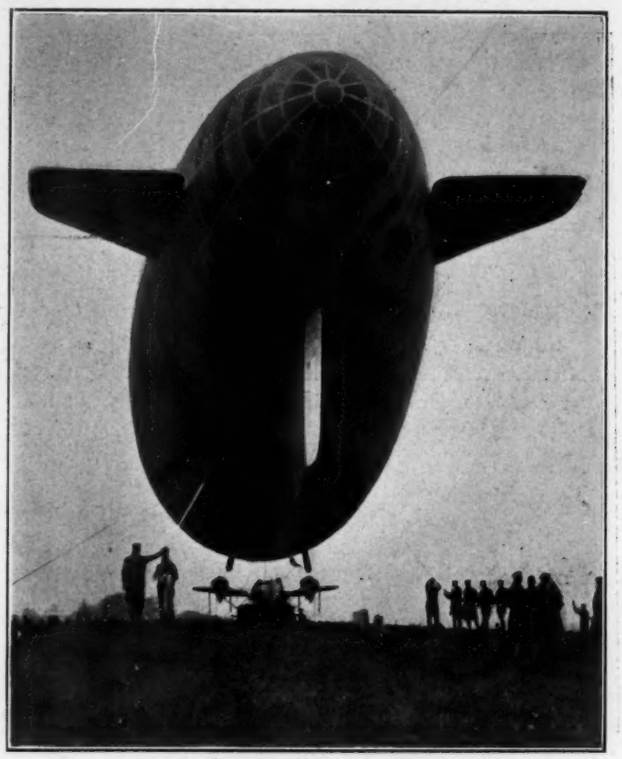


FIG. 4. C CLASS AIRSHIP, SHOWING SIMPLE DOUBLE-CAMBERED FINS

ernment contractors; but, in spite of a very great desire to help the Navy, it was immediately apparent that no one of them was in a position to handle the work. In the first place, they were without experience in airship building with the exception of the one unsuccessful attempt of the Connecticut Aircraft Co. None of the rubber companies had ever made fabric of the hydrogen resisting quality and strength required, and it would be necessary not only to develop new processes, but to put in new machinery and special equipment to manufacture it. Supplies of the special fine cotton cloth needed would have to be obtained, and the market for it was in an abnormal condition.

None of the firms represented had any building large enough to erect an airship, and, though the Navy was planning to put up eight airship sheds at coastal stations, the date of completion of such sheds was probably too remote to render them available for the first few ships turned out. It was of utmost importance that one ship should be rushed to completion in order to prove the design before the others were too far advanced.

It was agreed at the conference that the manufacturers should form a committee, which committee should arrange that each concern would bid for such proportion of the work as appeared to be within its capacity, that the raw materials, information and experience of all would be pooled both before and during manufacture, and that each would bid a flat price with a guarantee and bond. The present form of cost-plus contract or "Navy Order" was then unknown, and the bid price arrived at was purely an estimate based, to a large extent,

on information from abroad which the Bureau made available to the committee. The price agreed upon was about $40,000 per airship, with a guarantee to produce a practical ship making more than 35 mi.p.hr., and a guarantee to replace any defective parts for 3 months. As things worked out, most of the contractors lost money, for the work was done as a rush job and no expense was spared.

The Goodyear Co., as the most experienced, having built free balloons for a number of years, was in the best position to go ahead. R. H. Upson and R. A. D. Preston, aeronautical engineers of the Goodyear Co.'s staff, had had several years' experience in designing, making and practical handling of free balloons. They could be relied upon to cope with the present

FIG. 5. TEST OF A FINGER PATCH

problem. Goodyear agreed to put up at its own expense a complete erection and testing establishment consisting of a field near Akron, Ohio, with a large capacity hydrogen generating plant and an airship shed 200 ft. by 100 ft. by 100 ft., together with the barracks for the necessary field organization. This decision was reached March 20, 1917; ground was broken for the hangar and hydrogen plant April 1, 1917, and the first balloon (a free balloon) was inflated in the hangar June 1, 1917.

The Goodrich Co., to make up for its lack of experience in making airship envelopes, cabled for M. Julliot, the well-known engineer of the Lebaudy firm in Paris, whom they had been in correspondence with. M. Julliot sailed immediately, and later, when the United States had declared war on Germany, the department was able to arrange for the release from the French army of M. Julliot's assistants, M. Bourguignon and M. Gautier. These men, together with Mme. Bourguignon, who was a skilled fabric worker, were of the greatest assistance in introducing the practical refinements in manufacture about which information was so much needed.

The United States Rubber Co. decided not to attempt to build complete airships, but undertook to supply fabric for the Connecticut Aircraft Co.

First Trials

The Goodyear Co. completed the first airship in May, 1917, before their shed at Akron was completed. The Goodrich Co. had in the meantime found an abandoned shed at the "White City," Chicago; put it in order and arranged for a large supply of hydrogen in flasks. In order to get a trial of a type ship for the benefit of all contractors, it was arranged to ship the first Goodyear ship to Chicago. The ship was assembled, inflated and given a short flight by R. H. Upson, of the Goodyear Co. He was so favorably impressed with the results that on the second time up, the weather being favorable, he considered there was less danger in trying to fly home to Akron than in attempting a return to the little field at Chicago, which was seriously restricted by buildings and telegraph wires. Accordingly, he headed for Akron at midnight, and at noon of the next day, Decoration Day, 1917, landed in a meadow 10 mi. from Akron. Had the oil supply held out he could have landed on the Goodyear field, but the motor seized at the last minute.

The flight was remarkable in several particulars. In the first place, it was one of the longest airship flights on record up to that time. In the second place, it was a maiden flight of a new airship designed from theoretical and experimental data by a designer of no experience and built in two months by a firm without previous airship experience. In the third place, the flight is astonishing because Mr. Upson was not then an airship pilot, and by our present standards could not have been expected to handle the ship until he had gone through several weeks' instruction at the hands of an experienced pilot. However, he was an experienced balloonist, and as an engineer had a thorough appreciation of how the airship was designed to function. This flight was very encouraging for the production program, as it proved that the design was all right and permitted the contractors to go ahead with confidence.

From then on the ships were delivered with regularity, and by the end of the year were operating at the various naval air stations. The following table gives the dates of delivery of these ships:

No.	Manufacturer	Date	No.	Manufacturer	Date
B-1	Goodyear	July 19, '17	B-9	Goodyear	Jan. 31, '18
B-5	Goodyear	Aug. 11, '17	B-8	Goodyear	Feb. 25, '18
B-13	Goodrich	Sept. 11, '17	B-7	Goodyear	Feb. 27, '18
B-3	Goodyear	Oct. 22, '17	B-6	Goodyear	Mar. 3, '18
B-4	Goodyear	Dec. 4, '17	B-10	Goodrich	Apr. 15, '18
B-15	Connecticut	Dec. 14, '17	B-16	Connecticut	Apr. 15, '18
B-14	Goodrich	Jan. 11, '18	B-11	Goodrich	May 8, '18
B-2	Goodyear	Jan. 22, '18	B-12	Goodrich	June 6, '18

As the airships came along improvements and changes based on experience were incorporated. Suggestions for improvements in details of design came first from the contractors, and later, as more Navy pilots became trained, useful suggestions came from the service. The Goodyear Co. proposed many refinements in design, which they introduced as a result of the experience of their test pilots, Mr. Upson and Mr. Preston. The enterprise of that firm in providing a flying field at Akron, near their works, placed them in a position to experiment in the air.

Improvements in B Class

The improvements of most interest were those which led to an increase in speed. The first ships had a speed of about 40 m.p.h. It was found that one of the vertical fins could safely be left off, thus cutting down the resistance of one fin and its supporting wires. Later the car was suspended closer to the envelope, shortening the suspension and saving resistance. Still later, the suspension itself was simplified and knots and loops cleaned up. A somewhat longer and easier form of envelope gave greater lift and probably less, or at least no more, resistance. The air pipes to the ballonets were placed inside the envelope to save resistance. Improved propellers were developed also. The air scoop finally became only a short sheet metal tube hinged to the envelope proper, which could be let down into the slip stream of the propeller or pulled up out of the way, greatly decreasing the resistance and weight of the ship by eliminating the scoop under the car, the blower and air line to the bag.

As a result, the speed was progressively raised from 40 mi. to 48 mi. with the same engine. The designed maximum speed was 45 mi.p.h., but the contractors were required to guarantee 35 only.

A gratifying feature of the construction was the weight. If the ships had run over the designed weight their usefulness would have been seriously compromised. Fortunately, all ships, including the first of the series, showed a useful lift in excess of the designed load. In some cases it appeared that the structural weights would run over, but in those cases the buoyancy also ran somewhat in excess of the designed figures, leaving a good margin for the useful load.

The ships in service have more than fulfilled all expectations. Designed to cruise for 16 hr., a record on patrol of 40

hr. has been made with one of them at Key West. Aside from the short life of the fabric on some of the first ships, which was replaced, the ships have stood up well, and seven are still in use. One Goodrich ship was in continuous service with its original envelope for fifteen months. Another ship made by Goodyear kept one inflation of gas for nine months, and during this time was in the air 743 hr.

The Navy's first attempt to design, build and operate airships has been fraught with difficulties, but has been on the whole very successful. This is to some extent due to the modest size selected for the first attempt, but mainly to the energy and enthusiasm of the people concerned, both in and out of the service. The B class airships, as these sixteen were called, were used at home for training and coast patrol. In France our air forces operated French ships, and in England English ships. But though the B ships had no direct war service, they contributed their mite by training our pilots so that they could go abroad and take over immediately the operation of the foreign types. About 170 pilots were so trained in the United States on B ships before the armistice. In addition, B ships were used on coast patrol and flew over 13,600 hr., or about 400,000 mi.

The B class airships are in no way an improvement over contemporary English airships of the same type, and are in some respects less handy and simple, though of greater carrying capacity and endurance. The only noteworthy features are the conditions of their design, manufacture and initial operation. The ships were put into production from plans without waiting for the perfection of an experimental ship.

From the beginning the manufacture of a rubberized fabric for the envelope was recognized as the principal technical difficulty. The rubber companies had considerable experience in proofing fabric, but had never attempted anything to meet the rigid requirements now in effect. The specifications called for a life of six months in service, with high strength value and a low hydrogen permeability. The French specifications were copied exactly as to fabric. It was soon found that if over-cured the permeability was good but the life short, and vice versa. The quality of the fine cotton cloth used made trouble, and there were other difficulties which at the time seemed very serious but are now forgotten.

All contractors succeeded in doing what they had undertaken; to produce fabric in accordance with the specifications. The first few envelopes from one contractor perished quickly, but were promptly replaced with fabric coated with a different compound developed from this experience. Since then progress has been continuous, as more information has been obtained from our own experience and research and from abroad.

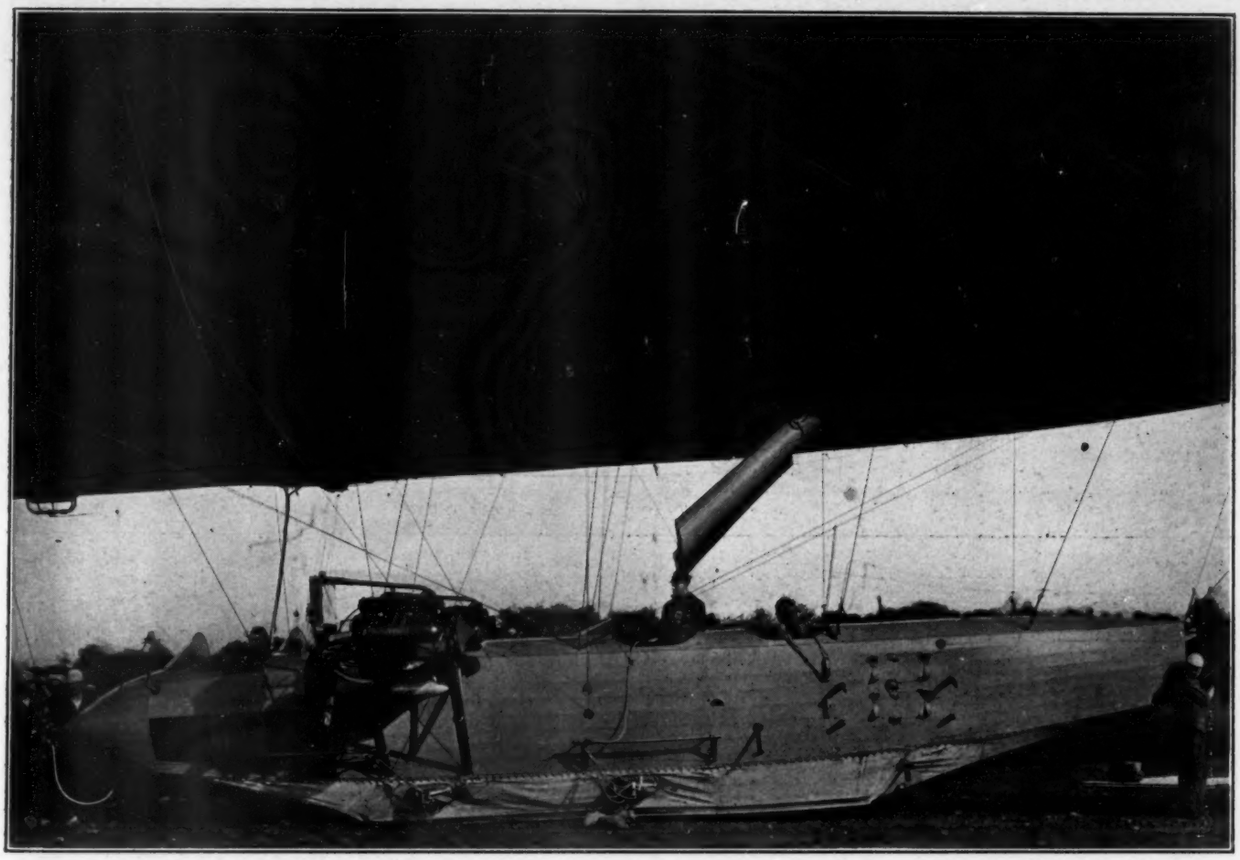


FIG. 6. CAR OF C-8, RIGGED TO FINGER PATCHES. NOTE ZAHM AIR SPEED METER ON THE BOW AND BOMB CLAMPS NEAR STERN

Balloon Fabrics

Fabrics for balloons and airships usually consist of cotton cloth coated with rubber. The requirements are high strength, light weight, low diffusion, water resistance and durability. The latter is the most important desideratum, and from extended observations it would appear that the life of rubberized fabric varies inversely with the intensity and time of exposure to sunlight. Attempts to devise an accelerated test, using artificial ultra violet light, have led to the conclusion that, while such light causes deterioration, the greatest rate of deterioration occurs on exposure to direct sunlight accompanied by high humidity and temperature. The Bureau arranged at the beginning of this work to have the Bureau of Standards put in testing facilities. At first, the Bureau of Standards was used as a check on the fabric-testing apparatus at contractors' works, but very soon the chemists of the Bureau of Standards began to contribute valuable suggestions for improvement, and at the present time are conducting research to develop better material.

A study of British and other foreign practice in fabric manufacture, combined with the results of extended exposure tests carried out under various climatic conditions with fabric made experimentally in this country for the purpose, has now led to the adoption of what is believed to be a marked improvement in rubberized fabric.

The cloth is very carefully inspected after manufacture, both before and after such treatments as desizing and washing. All slubs and imperfect spots are marked so that they may be cut out before rubberizing. In the rubber factories the cloth is first passed through spreading machines, where thin coats of dough (rubber cut with absorbed naphtha and similar volatiles) are applied. Carefully selected pure up-river Para gum is used for this purpose, and there is added only a very minor percentage of sulphur and litharge without the usual organic cure accelerators previously used. This thin rubber solution fills up the interstices of the weave. Much heavier rubber dough is then applied on the spreading machines as the process proceeds. Aftey twenty to twenty-five coats are spread and dried, a continuous, gas-tight film is produced.

The gas-tightness depends, however, upon such factors as the thickness of the rubber proofing and the count of the cloth; high count cloth and heavy proofing, giving the minimum diffusion. For instance, with 2-ply BB cloth having a gas film of from 3½ to 4 oz., there is obtained very low diffusion. Added weights of proofing applied to higher count cloth would probably produce but slightly better results than are obtained with the above construction. Two plies of the treated cloth are stuck together by means of roll-ply machines. The fabric is then wound on drums, wrapped and steam-cured at carefully controlled temperatures and pressures.

Over-vulcanization results in a fabric that ages rapidly, becoming brittle and stiff upon exposure. Examination of such fabrics upon exposure invariably shows high diffusion and rapid rise in acetone extract (indicating great oxidation). An acrid smell is always observed, and the rubber between the plies is hard and shows a lack of its original adhesive properties. Under-vulcanization is therefore the lesser evil, since exposure to the air and sun causes a certain degree of auto-vulcanization.

Yellow and red organic dyestuffs soluble in naphtha are often added to the proofing gum. These dyestuffs become thoroughly incorporated throughout the rubber solution and act as light screens in preventing the admission of sunlight to the rubber proofing. Yellow Cadmium Sulphide pigment is also used for this purpose.

The exterior surface of the fabric is coated with pure gum rubber dough containing usually a substantial proportion of litharge, which has been found to act as a screen or filter in preventing the admission of light rays to the rubber proofing. To the same exterior dough coating a quantity of finely divided aluminum powder is added, and then spread as the outer facing. The principle of this is to provide a continuous, light-reflecting coat. Fabrics made with such a coating have proved to be efficient in this respect, remaining usually 20 to 30 deg. Fahr. lower in temperature than similar fabrics without the aluminum facing. This aluminum coat is usually applied either with a spreader or a calico printing roll. In the latter case a larger number of coats are usually necessary on account of the thin character of the solution required for successful printing.

The inner or gas side of the fabric is coated with from one-half to one ounce of pure rubber, which helps to keep the cloth fungus and moisture-proof, reduces diffusion, and makes a good sticking coat for successful taping.

The exterior and interior seam tape is made fairly wide (2 in. or 3 in.), and contains a substantial amount of proofing. The exterior tape has an aluminum facing. Both tapes are now cut on the bias so that stretch may occur.

The seams in the envelopes of non-rigid airships constructed abroad are cemented with a pure gum cement consisting of solvent and fine para-rubber only. A cement of this character is entirely satisfactory where the temperatures to which the envelope is exposed rarely reach 95 deg.; but it was found that with the high temperatures prevailing in the United States during the summer this cement could not be depended on. General softening occurred, and the strength of the seam was reduced to the strength of the sewing, which is far below the strength of the fabrics used in making the balloon. One contractor, to overcome this difficulty, introduced a certain amount of resin into the cement which acted as a hardening agent. Even this was apparently insufficient, for when heated in an oven to a temperature of above 100 deg. Fahr., the seams made with this cement showed a tendency to slip on account of the softening of the cement. Another contractor who had accepted the European practice of using a strictly pure gum cement encountered great difficulties with the earlier envelopes on account of softening of the cement. He investigated this problem very thoroughly, and finally developed a method of applying the pure gum cement with a semi-curing solution, with the result that the seams apparently hold up to temperatures of 130 deg. Fahr. without softening. This practice is considered to be an important improvement.

(To be concluded)

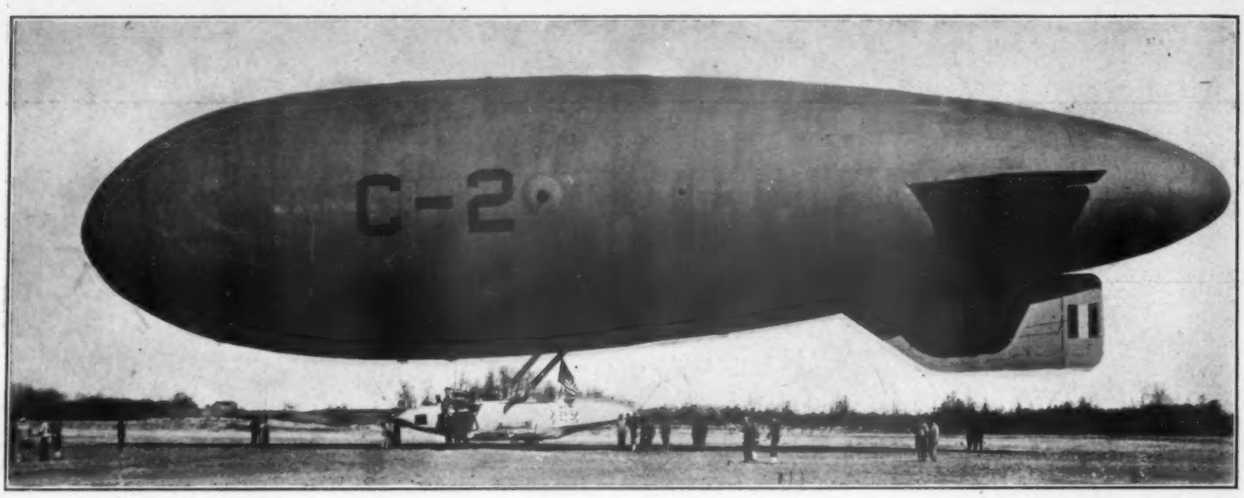


FIG. 7. AIRSHIP C-2. THE CAR IS SUPPORTED BY AN EXPERIMENTAL HORSESHOE PATCH SUSPENSION

Giant British Airship

The British Government has begun the construction of the largest airship that has yet been undertaken in any part of the world, one that will carry an equipment of six airplanes for its own protection against the heavier-than-air craft, according to recent reports.

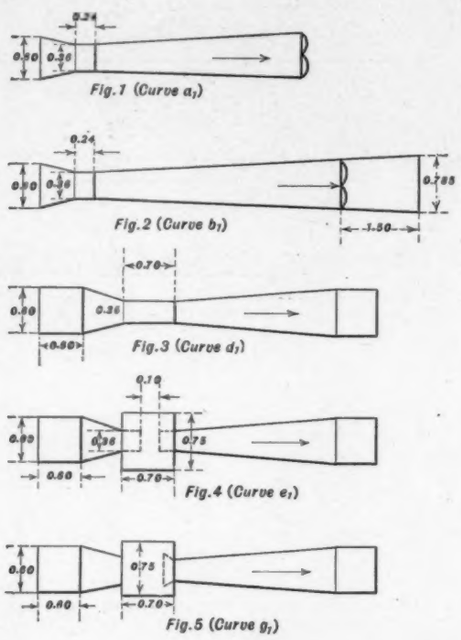
This airship and the two hangars to be built for it will cost $9,000,000. It will have a capacity of 10,000,000 cu. ft., will be 1100 ft. long, 137 ft. in diameter, and capable of lifting 100 tons, which would be about five times the lifting capacity of the R-34, which has just made a round-trip voyage across the Atlantic. The cruising radius of the new airship, which will be finished in from eighteen to twenty months, is given as 16,000 miles.

The Aerodynamic Experimental Tunnel

By W. Knight

The study of the forces acting on the different parts of an airplane during its flight is generally carried out in an experimental way on reduced size models of the parts to be investigated. This may be accomplished either by keeping the body stationary in a current of air which is moving at a velocity equal to that of the airplane in flight, or by moving the body, at this same velocity, through calm atmosphere.

It is evident that the first method is the more convenient of the two, and aerodynamic tunnels are built on this principle. A current of air of a desired velocity is produced by means of a fan, and this current is directed into a tunnel in which the parts to be experimented upon are conveniently supported by a suitable arrangement of levers and spring balances which measure the forces and the moments created by the air current striking the body.



It stands to reason that the guiding principle to be followed in designing an aerodynamic tunnel, is to obtain the desired air velocity with a minimum amount of power in a tunnel which is large enough to contain the parts under investigation.

Captain G. Costanzi and Colonel G. A. Crocco of the Italian Army, carried out a series of experiments on several models of various shaped tunnels, in order to determine the best design to adopt for a tunnel to be built in the Instituto Centrale Aeronautico in Rome. The conclusions reached by Captain Costanzi and Colonel Crocco, will be briefly presented in the present article.

Captain Costanzi experimented upon Venturi tubes of various shapes, and compared the power required at different air velocities in a given section of the tubes for obtaining a current of air through the tubes. He arrived at the following conclusions:

1. A minimum of power is required, when the experimental chamber, where the velocity of the air is measured (cylindrical section 0.36 m. in diameter, 0.24 m. in length), is connected at the air inlet to a truncated cone having an angle of 30 deg., and at the other end is connected to a truncated cone having an angle of 7 deg. (Fig. 1). Better results are obtained if the experiments are made in the open air rather than in a room.

2. The power required is still further reduced if the truncated cone at an angle of 7 deg. is extended beyond the fan, as shown in Fig. 2, all other dimensions of the tube being the same as in Fig. 1. By using this arrangement the velocity of the air at the outlet of the tube is less than before, consequently the loss of energy is less. It was also noted that in this case better results could be obtained by conducting the experiments in the open air and not in a closed room, therefore all the other experiments were also made in the open.

3. A third series of experiments was made with three tubes of the diameters shown in Figs. 3, 4, and 5. The angles of the cones of these tubes were the same as in case 1 (7 deg. and 30 deg. respectively). Figs. 4 and 5 show an arrangement by which the two cones, instead of being connected to a cylindrical chamber of the same diameter as the small end of the cones (as in Fig. 3) are connected to a larger cylindrical chamber. In Fig. 4 the distance between the two cones is only 0.10 m., and in Fig. 5 this distance is about 0.60 m. All the other dimensions are the same as in Fig. 3.

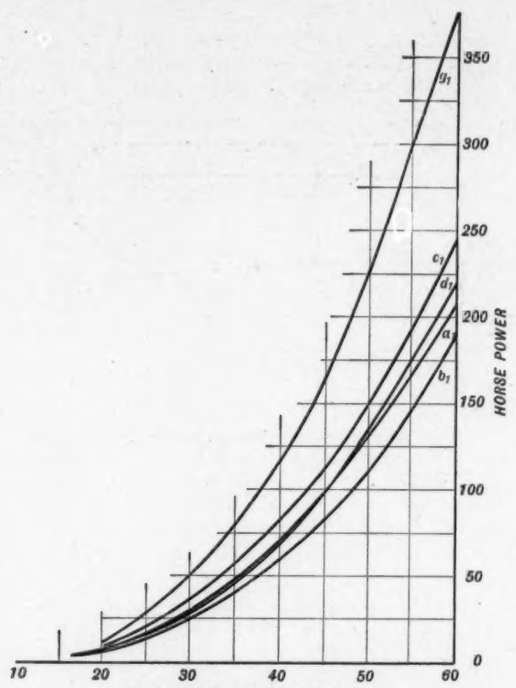


FIG. 6

The results of the tests proved that the power required for producing a current of air at the same velocity in the cylindrical section was least in the tube shown in Fig. 3, was greater in the tube shown in Fig. 4, and still greater in the one shown in Fig. 5. The results of these tests are indicated in Fig. 6. The curves *a, b, d, e, g* give results obtained from experiments made on tubes shown in Figs. 1, 2, 3, 4 and 5, respectively.

The experiments made by Captain Costanzi evidently gave rise to some well-defined principles regarding the best design of a tunnel. At the same time they all proved the advantage of conducting the experiments in the open air, or at least in a very large room. In order to avoid this inconvenience, Colonel Crocco conceived the idea of a closed type of tunnel with a continuous circulation of air. Besides avoiding the disadvantage of a large room as required for obtaining the best efficiency with Captain Costanzi's type of tunnel, the closed type utilizes the energy possessed by the air at its outlet (which is obviously lost when the discharge takes place in the open air), and, furthermore, allows a possible control of the temperature and humidity of the air circulated in the tube.

With a view of obtaining the best design of such a tunnel, the following experiments were made:

Tunnel with Two Return Circuits of Air

In the models experimented upon by Colonel Crocco, the central portion of the air circuit was designed according to

the indications resulting from experiments made by Captain Costanzi. As in the previous experiments, the influence of the length and the discontinuity of the observation chamber (cylindrical portion of the central air duct), the influence of extending or not extending the conical section beyond the propeller, and the influence of the section given to the air ducts for the return of the air to the inlet (square or circular section), were thoroughly investigated. In all cases the angles of the two cones were 7 deg. and 30 deg., respectively, at the entrance and at the outlet of the observation chamber.

Fig. 7 gives the chief dimensions of the central duct where the fan for sucking the air is mounted at the end of the 7 deg. cone. The cylindrical chamber, having the dimensions shown, is connected directly to the air ducts for the return of the air.

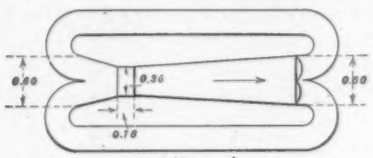


Fig.7 (Curve a)

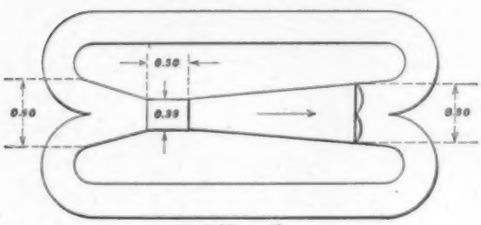


Fig.8 (Curve b)

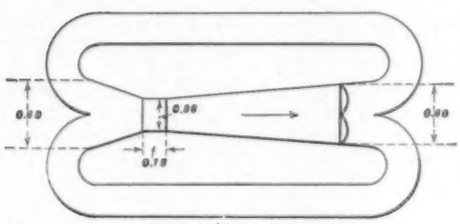


Fig.9 (Curve c)

These ducts are rectangular in section as far as the extremities of the cones.

Fig. 8 is similar to Fig. 7, except that the cylindrical section of the central duct is longer, and the return ducts, being square in section, gradually assume a circular section like that of the cones.

Fig. 9 is similar to Fig. 8, except that the length of the cylindrical section is the same as in Fig. 7.

Fig. 10 gives the chief dimensions of the central duct where the two cones at the ends are connected to two tubes of the lengths shown. These tubes gradually change from a circular section at their junction with the cones to a rectangular section at their junction with the air ducts for the return of the air, these latter being rectangular in section.

Fig. 11 is similar to Fig. 10, except that the cylindrical section of the main duct is continued into a larger concentric cylinder, closed at the ends, of the length shown and having an airtight door on the curved surface. The inner cylindrical tube is interrupted at the center for a length of 0.10 m., thus allowing a communication with the inside of the outer cylinder. When the door of the larger cylinder is open, the inside tube is in communication with the outer air, and when the door is closed the inside tube is in communication with the inside of the larger cylinder only. Curve *e*, shown in Fig. 13, indicates the conditions that exist when the door is closed; curve *f* indicates existing conditions with the door open.

Fig. 12 is similar to Fig. 11, except that the smaller tube concentric to the larger cylinder was removed, leaving only a short conical ring at the smaller end of the truncated cone.

The experiment was made with the door of the cylindrical chamber closed.

The experimental results of these are indicated in Fig. 13, where curves *a*, *b*, *c*, *d* correspond to the conditions shown in Figs. 7, 8, 9 and 10, respectively; curves *e* and *f* correspond to the conditions shown in Fig. 11 (door closed and door open), and curve *g* corresponds to the conditions shown in Fig. 12.

Conclusions

(1) A discontinuity over the length of the cylindrical tube, as shown in Fig. 11, gives rise to an increase of power required from the fan as compared with that required for the tunnel shown in Fig. 10; the power needed is even greater if

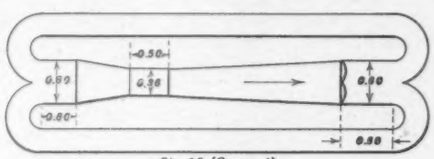


Fig.10 (Curve d)

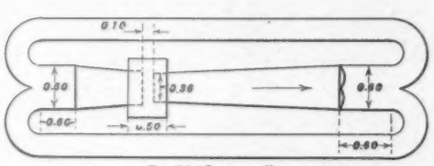


Fig.11 (Curve e,f)

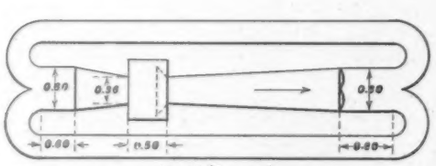


Fig.12 (Curve g)

the door to the outside cylinder is left open. The power demand increases still further if the smaller inside tube is left out altogether.

(2) The form of the section of the air ducts for the return of the air has also a slight influence on the power demand, being a little less if the section is circular instead of rectangular.

From the analysis of all these experiments, the type of tunnel which was finally adopted for the Instituto Centrale Aeronautico in Rome was the one shown in Fig. 10.

The advantages which might have been obtained by making the ducts for the return of the air of a conical section instead of rectangular were so slight that they were not considered, for constructive reasons.

The arrangement shown in Fig. 12 would have been a very convenient one, presenting all the advantages of a good sized room for containing the models or parts to be experimented upon. However, it was not adopted because it proved to be the least effective arrangement for carrying out experiments if the room was not airtight (see curves *e* and *f*). Considering the depression of the atmosphere in the room at a high wind speed, such a type of construction would have required a particularly strong and airtight structure, and would not have been so efficient, from a mechanical point of view, as the arrangement shown in Fig. 10 (see curve *d*), which was finally adopted for meeting all these requirements.

The data relative to a full size tunnel having a given diameter in the observation chamber (represented by D), as compared to the corresponding diameter of the model experimented upon (represented by d), can be calculated according to the following formulas:

V_1 = wind speed in observation chamber of model tunnel.

V = wind speed in observation chamber of full size tunnel.

N_1 = r.p.m. of fan used for model tunnel for wind speed $= V_1$.

N = r.p.m. of fan used for full size tunnel for wind speed $= V$.

HP_1 = horsepower required for model tunnel for a wind speed V_1.

HP = horsepower required for full size tunnel for a wind speed V.

$$\alpha = \frac{D}{d}$$

$$V = V_1 \times \sqrt{\alpha}$$

$$N = N_1 \times \frac{1}{\sqrt{\alpha}}$$

$$HP = HP_1 \times \alpha^2 \times \sqrt{\alpha}$$

The chief dimensions adopted for the Aerodynamic Tunnel

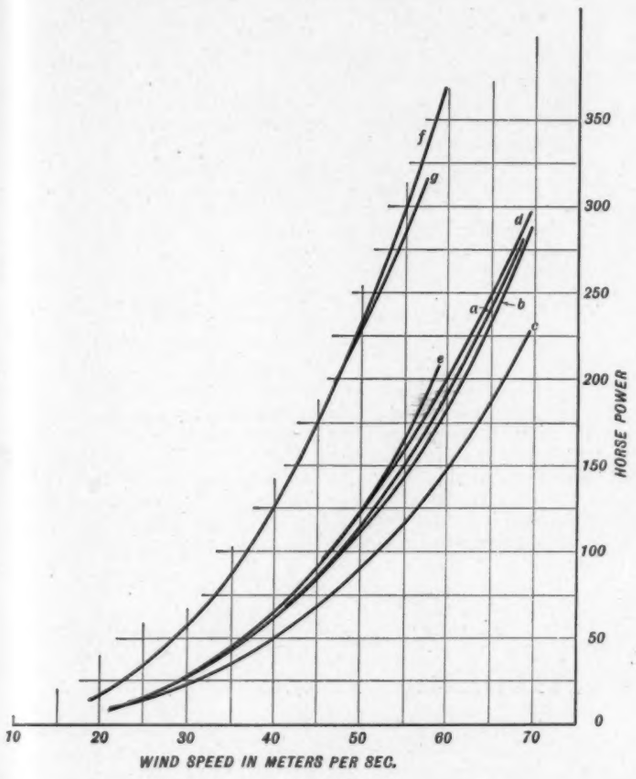


FIG. 13

built in the Instituto Centrale Aeronautico, Rome, after the experiments described above, are given in Fig. 14.

The air is admitted through the square section *a*, which is joined to the base *c* of the truncated cone, by means of *b*. The air is admitted through *d* to the experimental chamber *f*. This latter is connected at *g* to the truncated cone *h* near the end of which the fan is installed. The conduits for the return of the air are rectangular in section and are joined to the entrance *a* and to the outlet *i* of the main tunnel.

The fan used is a propeller with seventeen wooden blades. This was adopted after careful experiments had been made on several small size models, in order to determine the most effective design. The efficiency of the fan used is 0.75. It is driven by an A. C. 210 hp., 220-volt, three-phase motor making 640 r.p.m. The current for the motor is supplied by a D. C. generator, 145 kw., 10/500 volts, 640 r.p.m.

The power required for corresponding velocities of the air in the experimental chamber is given in the following table. In the right-hand column the ratio $e_t = \frac{P_u}{P_m}$, where P_m = thrust required on the fan shaft and P_u = thrust of the air in the experimental chamber.

Velocity of the air in meters per sec.	R.p.m. of the fan	Horsepower required	$e_t = \frac{P_u}{P_m}$
10	90	..	..
20	186	7	3
30	285	27	2.62
40	372	60	2.8
50	458	113	2.9

The air collector (*b* and *d*) is made of wood, and the angle of the cone is 30 deg.

The experimental chamber *f* is made in two sections; one section adjacent to the collector (2 m. dia. by 1 m. long) made

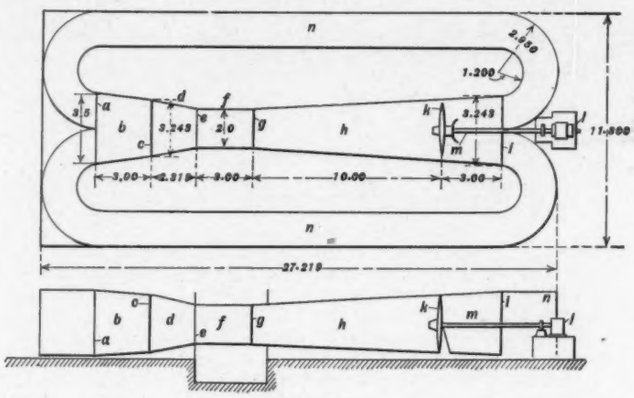


FIG. 14

of wood, the other section (2 m. dia. by 2 m. long) made of sheet-iron, with doors on the sides for the admission of models and parts to be experimented upon. These two sections are separated by a cellular diaphram made of thin sheet metal, which compels the air to pass through a large number of cells 5 cm. square by 20 cm. long, having their axes parallel to the axis of the tunnel. This is done in order to obtain a parallel flow of the air currents reaching the experimental chamber.

The diffuser has the form of a truncated cone of 7 deg. It

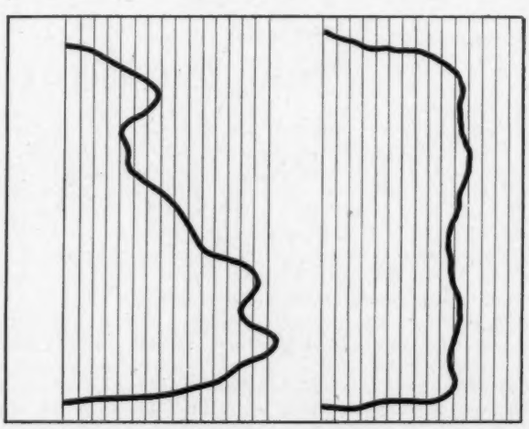


FIG. 15

is made up of canvas, which is painted to render it impervious to the air, and it is held in place by means of a convenient iron structure.

The two ducts for the return of the air are made of cement and are rectangular in section, 1.75 m. by 3.50 m.

Both the collector and the experimental chamber are located in a room having airtight doors communicating with the outside. The room is lighted by a skylight, and it is here that the instruments and balances are located.

The advantages offered by Crocco's type of tunnel with a closed circuit for the circulation of the air are due chiefly (as

already pointed out) to the elimination of the influence of the surrounding walls of the room in which the tunnel is installed, unless a very large room is used for this purpose, as would be the case with an airship hangar. In this case the air in the room would be practically still and the influence of the walls would be negligible, on account of their comparatively great distance from the entrance and the outlet of the tunnel. This eliminates the losses of power resulting from the impact of the air against the walls of the room in which the tunnel is installed, these losses increasing in magnitude as the dimensions of the room decrease.

Tunnel with One Duct Only for the Return of the Air

Tunnels having only one duct for the return of the air to the chamber where the experiments are made have given very poor results.

In the Aerodynamic Institute at Göttingen, in 1909, there was a tunnel having a cross section of 2 sq. m., the axis of

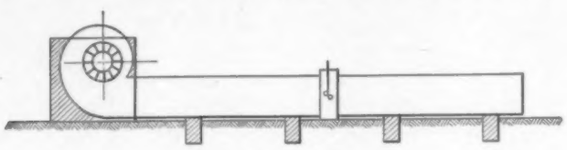


FIG. 16

the tunnel forming a rectangle, in which the maximum wind speed obtained was 10 m. per sec. At first this tunnel led to some very poor measurements of the air velocity at different points of the tunnel cross section.

Professor Prandtl experienced all kinds of difficulties in attempting to equalize the air velocity at different points of the tunnel cross section, for the maximum velocity only, of the air. The equalization was obtained by screwing the air more or less at several points of the cross section. Fig. 15 gives a diagram of the air velocity at different points of the cross section where the experiments were made before and after correction, and for a wind velocity of only 10 m. per sec.

In 1907, Colonel Crocco built a tunnel at the Laboratory Brigata Specialisti which had a cross section of 2 sq. m. and a length of 22 m. (see Fig. 16). This tunnel presented the same difficulties as the one at Göttingen, and had to be abandoned after a few years of unsuccessful attempts to make it work properly.

In all cases, when one single duct is used instead of two for the return of the air to the tunnel, the lack of symmetry in the air current, under the influence of the centrifugal force of the air and the walls of the tunnel, gives rise to the formation of air filaments which follow a sinuous path in the air current, as shown in Fig. 17. The position of the restricted vein *AB*, where the air has a maximum velocity, varies according to the speed of the fan.

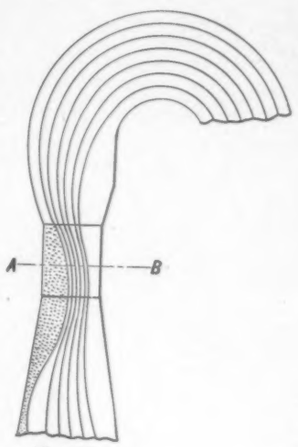


Fig. 17

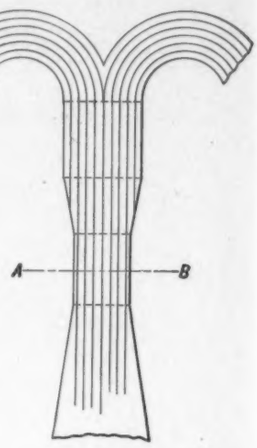


Fig. 18

When, instead of one duct, two symmetrical ducts are used for the return of the air, the prevailing conditions of the air flow are like those shown in Fig. 18, and an almost perfect equalization of the air velocity is obtained at every point of the cross section of the tunnel.

These two points have been verified by Colonel Crocco, with experiments made in the old tunnel at the Laboratory of the Brigata Specialisti, and in the new tunnel at the Instituto Centrale Aeronautico in Rome, Italy.

New York-Toronto Airplane Race

An international airplane race and handicap contest will be run on Aug. 25 by the American Flying Club and the Aero Club of Canada under the rules and regulations promulgated by the American Flying Club, with pilots and airplanes licensed by the U. S. Joint Army and Navy Board of Aeronautic Cognizance. The contestants are to start simultaneously from New York and Toronto over a round trip circuit with compulsory control and inspection stops both ways at designated flying fields located in Albany, Syracuse and Buffalo, N. Y. The total distance to be covered is approximately 1,040 miles, with distances between control aerodromes as follows: New York-Albany, 149 miles; Albany-Syracuse, 141 miles; Syracuse-Buffalo, 146 miles; Buffalo-Toronto, 85 miles.

The object of the contest is to promote the science and sport of aviation in a manner reflecting its safety, permanence and reliability, and is open to all approved types of airplanes excepting seaplanes of either float or boat type. Contestants will compete for a cash prize of $10,000, offered by John McE. Bowman, president of the Hotel Commodore, which is divided into nine handicap prizes totalling $7,500 and into three speed prizes totalling $2,500. In addition there are also offered for competition by entrants, while competing for the Hotel Commodore prizes, the Canadian Exhibition Trophy, the Aero Club of Canada Trophy and the American Flying Trophy.

Competition for prizes will be open to members of the American Flying Club and affiliated clubs, and the Aero Club of Canada who hold aviator and hydro-airplane licenses issued by the U. S. Joint Army and Navy Board of Aeronautic Cognizance, and pilot's certificates issued by the Aero Club of Canada. The entry fee is $50 per airplane; entries will be received up to midnight of Aug. 23, 1919. Entry forms and a set of rules and regulations governing the contest may be had upon application at the American Flying Club, 11 East 38th Street, New York.

The award of the handicap prizes will be determined by the following formula, expressing efficiency and reliability in airplane performance:

$$\frac{\text{Flight Load} \times \text{Distance of Prescribed Course}}{\text{Horsepower} \times \text{Actual Time}} \times \text{Index Factor}$$

The index factor will be calculated from the apparent best performance among the entries, and each other machine will be handicapped therefrom in order to render each airplane's equation initially equal. The winners of the handicap prizes will be the entrants who show in order of merit the nine most creditable performances under the given rules and regulations.

The Hotel Commodore speed prizes and the three trophies will be awarded in order of merit to the contestants making the round trip circuit in the shortest total flying time. The Canadian National Exhibition Trophy will be awarded upon the basis of the shortest flying time made by any contestant over the round trip course; the Aero Club of Canada and American Flying Club trophies will be awarded to the American and Canadian entries, respectively, making the best time either way between Mitchell Field, L. I., and Leaside, Toronto, Ont.

Course in Aerodynamics and Airplane Design

Part III.—Experimental Aeronautical Engineering

By Alexander Klemin

Technical Editor, Aviation and Aeronautical Engineering; Consulting Engineer, Aerial Mail Service; Consulting Aeronautical Engineer

Section 7. Climb and Speed-at-Altitude Tests

Climb and Speed-at-Altitude Tests

After the air speed indicator has been calibrated the climbing and speed-at-altitude tests may be conducted.

Try-out climbs.—While it is easily possible for almost any pilot to obtain the maximum speed of the airplane at any given altitude, it is a matter of considerable skill to get the best possible climb out of a machine. At ground level, if curves of horsepower required and horsepower available are drawn, it will be found that there is some one speed at which the excess horsepower is a maximum. This is, of course, the best climbing speed at ground level. It is found in practice, although not strictly true theoretically, that if the air speed meter reading is maintained equal to that which gives the best climb at ground level, the best rate of climb will be maitained. A few preliminary try-out climbs are recommended to determine this air speed reading.

Instruments required.—The instruments required in the two cockpits for the climb and speed-at-altitude tests are as follows:

Pilot's cockpit:

(a) Revolution counter.

(b) Altimeter. This should be set to correspond with barometric pressure on the ground, and not to zero.

(c) Radiator thermometer, so that heating of the motor may be observed.

(d) Direct reading air speed indicator. This is not required to take observations but to enable the pilot to check his climbing speeds.

(e) If possible, a maximum climb indicator.

Observer's cockpit:

(a) Direct reading of recording tachometer.

(b) Direct reading or recording altimeter. This should be set to correspond with barometric pressure on the ground, and not to zero.

(c) Direct reading or recording air speed indicator.

(d) Direct reading or recording strut thermometer.

(e) Stop watch.

Some thought should be given to the selection of the barograph. The scale of this instrument should be appropriate to the climb undertaken and the time scale also should be sufficiently extended. The strut thermometer should be placed in a position where it will not be affected by the exhaust gases, and if not connected to the instrument board it should be sufficiently large so that it can easily be read from the pilot's or observer's seats.

Procedure in Climb and Speed-at-Altitude Tests.—A well-defined procedure should be followed in making these tests. Where recording type instruments are used, the only difficulty to be anticipated is in the synchronization of the instruments described in the foregoing paragraph.

Where direct reading instruments are used the observer has a rather difficult task. At every 1000 ft. as shown by the aneroid, he must mark on his pad or report: the time since the start, the strut temperature, the air speed reading and the r.p.m. of the engine. When the pilot has reached the ceiling, which he determines by the rate of climb becoming so small as to be imperceptible, he gives the plane a straight flight at full throttle, then dives to a lower altitude and at this altitude executes a straight flight at maximum speed. During this straight flight the observer again marks down the air speed, the engine speed and the strut temperature. The flights at altitudes are repeated at various levels. It is very important in this work that the straight flights be of sufficient duration to enable correct readings to be taken.

Typical Climb and Speed Tests

Climb.—In order clearly to illustrate the methods followed, a typical test run will be followed through very carefully. This test was run with a plane fitted with a Liberty-12 engine and direct-drive propeller. The observer's report for this test is given in table I. The reduction of the results is based on the method described by Capt. H. T. Tizard in *The Aeronautical Journal,* and is related to the standard density at altitudes employed by the British.

The calculation of results requires some care. These calculations are summarized in table II. In columns 1, 2, 4, 9 and 10 are tabulated the observations made on the test, after making corrections for instrumental errors from calibration curves, such as the calibration curve for the air speed meter. In column 3 are tabulated the pressures corresponding to altimeter readings.

TABLE I
OBSERVER'S REPORT

Date: May 14–918. Test No.....
Airplane: DeH.-4—P—31.
Temperature on ground 55 deg. Fahr. Pressure on ground 29.3 in. mercury

Altitude	Climbing Test			R.P.M.	Speed at altitude		
	Time	Temperature Deg. Cent.	Air speed m.p.h.		Speed	R.P.M.	Temperature Deg. Cent.
1,000	0:55	20	55	1,550			
2,000	1:50	19	58	1,550	120	1,780	22
3,000	2:45	17	58	1,540			
4,000	3:55	12	55	1,540			
5,000	4:55	12	58	1,540	112	1,750	15
6,000	6:00	10	55	1,530			
7,000	7:30	7	55	1,530			
8,000	8:45	5	60	1,530	105	1,700	10
9,000	10:05	4	60	1,520			
10,000	11:35	3	60	1,520	105	1,700	8
11,000	12:10	3	58	1,510			
12,000	15:05	2	55	1,500	100	1,690	8
13,000	17:35	2	58	1,500			
14,000	19:50	1	55	1,490	90	1,650	5
15,000	23:00	—1	55	1,490			
16,000	29:00	—2	50	1,460	85	1,600	0
17,000	36:50	—5	55	1,460			
18,000	46:30	—8	55	1,470	80	1,570	—6
19,000	52:00	—9	58	1,460			
20,000	59:00	..	55	1,460	70	1,510	—9

TABLE II

REDUCTION OF DATA—CLIMBING TEST

Observed aneroid height	Time	Corresponding pressure in in. of mercury	Temperature at strut	Density	Corresponding standard height	Aneroid rate of climb	Corrected rate of climb	Observed air speed	R.P.M.
0	....	29.30	25	....					
1,000	0:55	29.30	22	.941	2,725	1,130	1,181	58	1,550
2,000	1:50	27.79	21	.911	3,720	1,055	1,100	61	1,550
3,000	2:45	26.79	20	.884	4,700	1,010	1,050	61	1,540
4,000	3:55	25.82	15	.855	5,670	965	988	58	1,540
5,000	4:55	24.90	15	.834	6,480	895	910	58	1,540
6,000	6:00	24.00	15	.811	7,290	780	792	63	1,530
7,000	7:30	23.14	10	.789	8,100	745	748	63	1,530
8,000	8:45	22.31	8	.766	9,040	720	717	63	1,530
9,000	10:05	21.51	7	.742	9,950	705	700	61	1,520
10,000	11:35	20.73	6	.716	11,030	635	627	58	1,520
11,000	13:10	19.99	6	.691	12,100	570	563	61	1,510
12,000	15:05	19.27	5	.668	13,120	517	508	58	1,500
13,000	17:35	18.58	5	.646	14,340	443	435	58	1,500
14,000	19:50	17.91	4	.623	15,400	350	343	53	1,490
15,000	23:00	17.25	2	.605.	16,260	233	227	58	1,490
16,000	29:00	16.65	1	.586	17,220	140	136	58	1,460
17,000	36:50	16.05	—2	.571	18,000	110	106	61	1,460
18,000	46:30	15.47	—3	.558	8,640	96	74	58	1,470

In column 5 is tabulated the ratio of density to standard air at 16 deg. Cent. and 760 mm. of mercury. In column 6 are given the standard heights corresponding to these ratios of density. To obtain the aneroid rate of climb given in column 7 an auxiliary curve is required. In Fig. 1 the observed climbs are plotted without corrections against the time of climb. Then at any altitude the aneroid rate of climb is obtained from the slope of the tangent to the curve, as is quite evident from this figure.

Column 8 gives the aneroid rate of climb corrected for temperature. This correction is obtained by the formula

$$H = \frac{273 + \theta}{273 + 10} \times h$$

where θ is the temperature in deg. Cent. at the point under consideration.

The corrected rates of climb are now plotted against the standard heights given in column 6, as shown in Fig. 1. These points should lie almost, if not quite, in a straight line. Through the points a smooth curve is plotted, and from this curve the rates of climb corresponding to the even thousands of feet in thousands of feet in standard air can be read. Knowing the rate of climb for each 1000 ft., the time of climb to any required height can be computed.

For example, to compute the time of climb to 1,000 ft. the average rate of climb is

$$\frac{1335 + 1275}{2} = 1305 \text{ ft. per min.}$$

The time is therefore

$$\frac{60 \times 1000}{1305} = 46 \text{ sec.}$$

To 2000 ft. the average rate of climb is

$$\frac{1275 + 1215}{2} = 1254 \text{ ft. per min.}$$

The time is therefore

$$\frac{60 \times 1000}{1245} + 46 = 1 \text{ min. } 34 \text{ sec.}$$

To 3000 ft. the average rate of climb is

$$\frac{1215 + 1155}{2} = 1185 \text{ ft. per min.}$$

The time is therefore

$$\frac{60 \times 1000}{1185} + 1{:}34 \doteq 2 \text{ min. } 24 \text{ sec.}$$

The results of these computations are plotted in Fig. 2. In table III are given the r.p.m. values against standard heights.

It should be noted that the quickest way of obtaining the theoretical ceiling is to produce the rate of climb against standard altitudes until the curve intersects the ordinate at the origin. This intersection determines the altitude. Generally the decrease in the rate of climb is proportional to altitude, and the curve can be represented by a straight line. In drawing this curve it has been suggested that more weight should be given to the points above 5000 ft. than below, since above this height the performance is more regular.

Service ceiling.—This is determined by the pilot at the point where the rate of climb is less than 100 ft. per min.

Speeds at altitudes.—After the pilot has climbed to the service ceiling of the machine and begins the descent, he levels off at different altitudes, as previously explained, and flies level for a full minute at each altitude. It is necessary to fly level

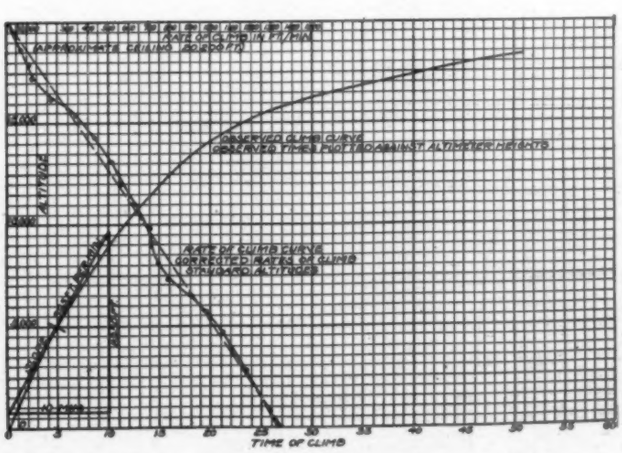


FIG. 1. CORRECTED RATES OF CLIMB PLOTTED AGAINST STANDARD HEIGHTS

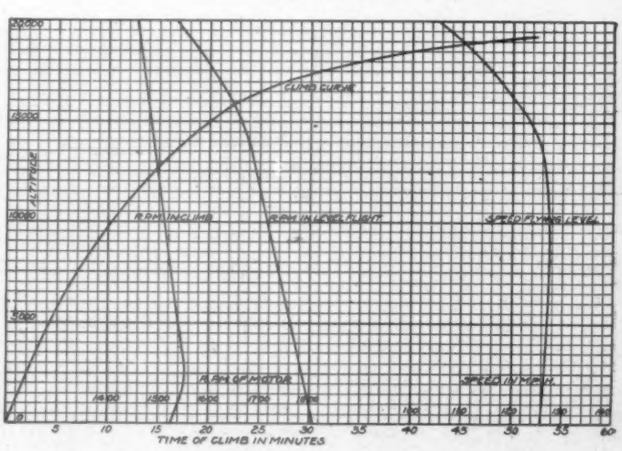


FIG. 2. CURVE OF TIME AND RATE OF CLIMB TO EACH 1000 FT.

TABLE III

RESULTS OF CLIMBING TEST REDUCED TO STANDARD AIR

Altitude in standard air	Time	Rate of climb	R.P.M.
1,000	0:46	1,275	1,540
2,000	1:34	1,215	1,550
3,000	2:24	1,155	1,550
4,000	3:17	1,095	1,545
5,000	4:14	1,030	1,540
6,000	5:15	945	1,530
7,000	6:23	830	1,525
8,000	7:39	750	1,520
9,000	9:01	710	1,515
10,000	10:27	685	1,510
11,000	11:59	635	1,505
12,000	13:39	570	1,500
14,000	17:37	450	1,490
15,000	20:01	380	1,485
16,000	23:06	270	1,480
17,000	27:48	155	1,475
18,000	35:29	105	1,470
19,000	47:59	55	1,465

by multiplying it by the inverse square root of the ratio of density to standard air, as shown in Figs. 1 and 2.

In column 8 is recorded the speed of the engine at each altitude, after correcting in accordance with the calibration of the tachometer.

Example.—Take the computations for the speed at 2000 ft. The pressure corresponding to the aneroid height of 2000 ft. is found on reference to be 28.83 in. mercury. With this pressure and a temperature of 25 deg. Cent. the ratio of density to standard density is found to be equal to 0.935. This relative density gives a height of 2900 ft. on the curve of standard heights. The corrected air speed therefore is

$$\frac{123}{\sqrt{0.935}} = 127 \text{ m.p.h.}$$

The corrected air speeds and engine revolutions are plotted on cross-section paper against standard altitudes. Through the plotted points smooth curves are drawn, and from these curves the air speed and engine r.p.m. corresponding to the 1000 ft.

TABLE IV

REDUCTION OF OBSERVED DATA—SPEED TEST

Observed altitudes	Corresponding pressure in in. of mercury	Strut temperature deg. Cent.	Relative density	Corresponding standard height	Air Speed Indicator Reading	Corresponding air speed	R.P.M
2,000	28.82	25	.935	2,900	123	127.0	1,780
5,000	24.90	18	.825	6,700	115	126.5	1,750
8,000	22.31	13	.754	9,500	108	124.2	1,700
10,000	20.73	11	.704	11,600	108	128.8	1,700
12,000	19.27	11	.652	14,000	103	127.5	1,690
14,000	17.91	8	.614	15,800	93	118.8	1,650
16,000	16.65	3	.583	17,800	88	115.0	1,600
18,000	15.47	—3	.553	18,800	83	110.4	1,570
20,000	14.37	—6	.515	20,800	73	101.8	1,510

for at least this length of time in order to permit conditions to balance themselves and a steady speed to be attained. When the pilot flattens out and makes his level flights the observer notes the altitude, air speed, strut temperature and engine speed as shown in Table I. These observations are later reduced, using the form shown in table IV.

Column 1 (table IV) contains the altitudes as read from the altimeter. In column 2 is given the pressure in inches of mercury corresponding to the observed height. This is read from the altimeter calibration curve. The observed temperatures are recorded in column 3, after calibration correction has been applied. In column 4 the proportion of standard density is given.

The altitude in standard air corresponding to density is filled in in column 5. The observed air speed indicator reading, after being corrected for errors determined by calibration, is given in column 6. In column 7 the air speed is corrected for density. As the air speed meter has been calibrated to read correctly at standard density (corresponding to 29.92 in mercury at 16 deg. Cent.) the speed at any other density must be corrected

standard heights are taken. These values, the results of the speed test, are entered in table V. The climb, speed and engine r.p.m. curves for these tests are shown in Fig. 2.

TABLE V

RESULTS OF SPEED TESTS TAKEN FROM CURVES

Standard altitude	Speed	R.P.M.
2,000	126.4	1,788
3,000	126.6	1,780
4,000	126.8	1,770
5,000	127.0	1,760
6,000	127.0	1,752
7,000	127.2	1,744
8,000	127.4	1,735
9,000	127.4	1,725
10,000	127.4	1,716
12,000	127.0	1,700
14,000	125.0	1,680
16,000	121.0	1,645
18,000	114.0	1,595
20,000	104.5	1,535

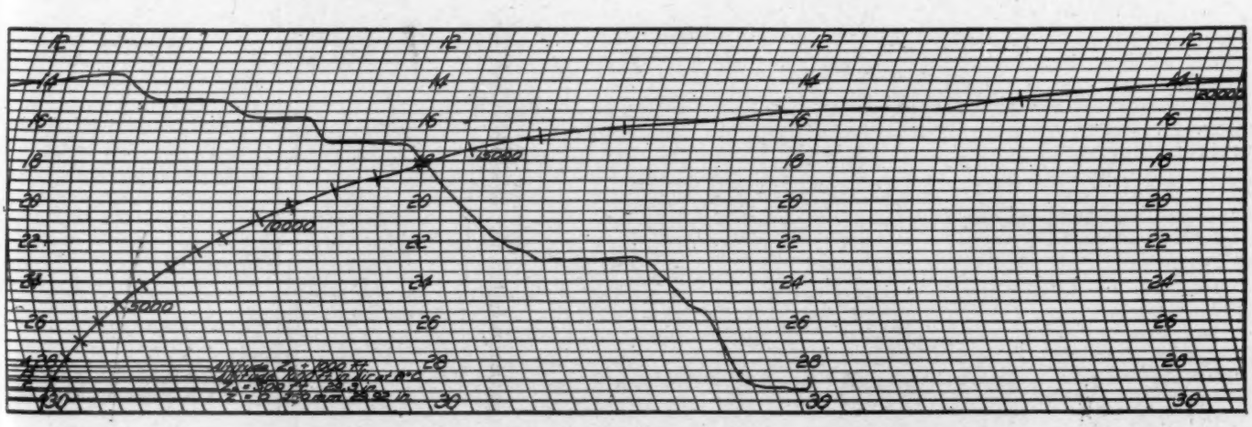
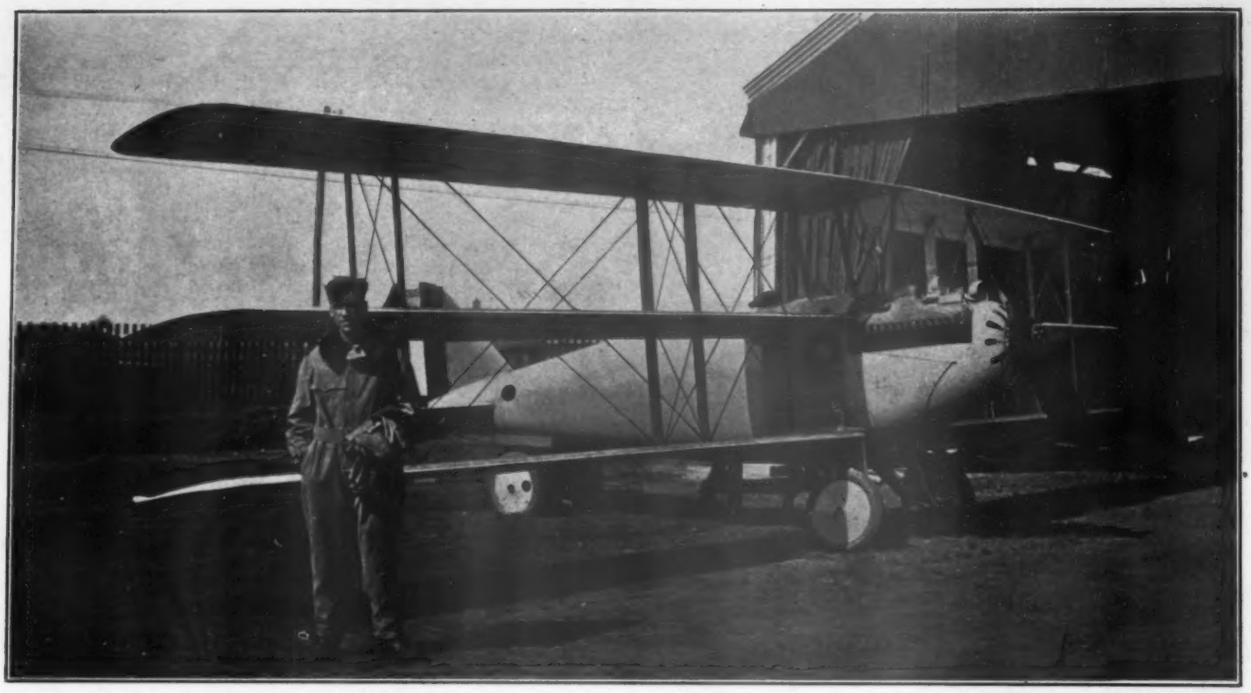


FIG. 3. TYPICAL BAROGRAPH CHART OF A TEST

New World's Altitude Record

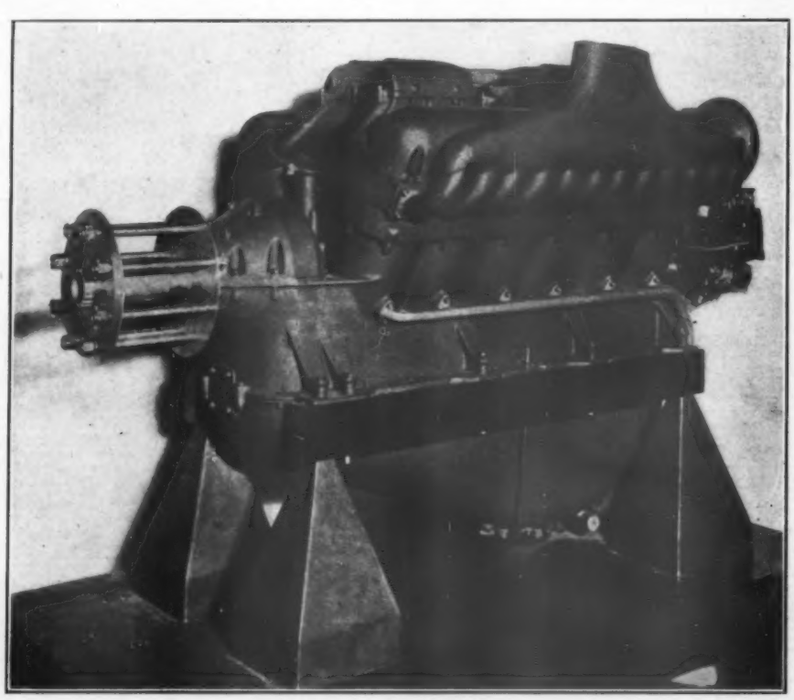


ROLAND ROHLFS STANDING BESIDE THE RECORD-BREAKING CURTISS WASP ON WHICH HE REACHED AN ALTITUDE OF 30,700 FT. A NEW WORLD'S ALTITUDE RECORD

Roland Rohlfs, test pilot for the Curtiss Engineering Corp., established on July 30, at Roosevelt Field, L. I., a new official world's record by reaching an altitude of 30,700 ft., thus breaking the world's record previously held by Major (then Capt.) R. W. Schroeder, U. S. A., with 28,900 ft., which he established on Sept. 18, 1918, at McCook Field, on an American built Bristol biplane fitted with a 300 hp. Hispano-Suiza engine, Model H.

Rohlfs used in his record-breaking flight a Curtiss Wasp triplane, which is fitted with a Curtiss K-12 400 hp. engine. This machine is a modification of the Curtiss 18-2 triplane (which was described in the February 15, 1918, issue of AVIATION AND AERONAUTICAL ENGINEERING); the wings are 32 ft. ½ in. in span and are set at a slight sweepback, with two bays of interplane struts per wing.

The flight was made under official auspices, being witnessed by a board appointed by Col. Archie Miller, C. O. of the Air Service fields on Long Island.



CURTISS K-12 400 HP. ENGINE

Rohlfs, who left the ground at 2.33 p. m., found himself in a temperature of 25 deg. below zero, with a wind blowing 100 miles an hour, when he reached the top of his climb of nearly six miles, the intense cold causing trouble with his engine. He cut up the pillow of his seat and tried to use the stuffing to protect parts of the engine from the cold, but this was blown away as fast as he put it in place. Rohlfs then climbed out on his machine to cut a water pipe when he thought that cold water from the pipe was helping to chill the engine, but he found it difficult to leave the controls unguarded, and finally had to start downward, landing at 5.28 p. m.

Rohlfs shortly intends to make another altitude flight in which he hopes to reach the 35,000 ft. mark to surpass the record made by Sub-Lieut. Casale of the French Air Force, who reached on June 14, at Villacoublay, France, an altitude of 10,100 meters (33,136 ft.). This performance has not as yet been certified by the Aero Club of France as an official world's altitude record.

The Design of Hollow Interplane Struts

By Armin Elmendorf

Engineer in Forest Products, Forest Products Laboratory

The superiority in strength per unit of weight of hollow columns over solid columns has long been recognized and utilized. In airplane construction another factor must be considered, for it reduces the apparent superiority of the hollow construction over the solid construction. Airplane struts are exposed to the air in flight and contribute very appreciably to the parasite resistance of the plane and any increase in the breadth of the strut increases this resistance. Since hollow struts present a greater breadth to the air than do the solid struts of the same material and strength, their increased air resistance may in some cases overbalance the advantage of reduction in weight.

Coefficients of resistance for airplane struts vary with the strut sections, so that no comparison between the struts can be made unless the section is known and its coefficients have been determined for various speeds. The following discussion will, therefore, be restricted to struts or columns having

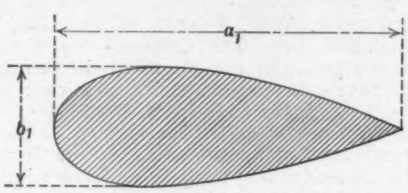


FIG. 1. SOLID STREAMLINE STRUT

the same section, which, it will be assumed, is of constant size throughout the length of the strut. In this way the question of comparative air resistance is entirely eliminated, and the analysis may be confined to a study of the distribution of stresses within the strut.

The effect of modulus of elasticity on strength, position of the material to obtain maximum strength, shear stresses, and the buckling of hollow struts are each considered.

The maximum load that a strut supported on knife edges and of constant section throughout the length will sustain is given very closely by Euler's column formula, $P = \frac{\pi^2 EI}{L^2}$ in which P is the load, E is the modulus of elasticity of the strut material, I is the moment of inertia of the section, and L is the strut length.

Effect of Modulus of Elasticity

Assuming the same length, it is seen from Euler's formula that the maximum load varies directly as the modulus of elasticity of the material and the moment of inertia of the section. The modulus of elasticity of steel is about 30,000,000, that of birch about 2,200,000 at 9.6 per cent moisture, and of spruce 1,600,000 at 9 per cent moisture. When, however, the weight of the different materials is taken into consideration, we find that in comparing the ratio of modulus of elasticity to weight for steel with the corresponding ratio for wood, the ratio for steel is about the same as that for spruce and somewhat greater than that for birch at these moisture contents. The high modulus of elasticity of steel is, therefore, not a particular mark of superiority of that material over wood.

Effect of Distribution of the Material

The second variable that affects the magnitude of the load a strut will sustain is the moment of inertia of the section, which, in turn, varies directly as the cube of the least cross-sectional dimension. A 10 per cent increase in the width, for example, should increase by 33 per cent the maximum load the strut will sustain. However, the considerable increase in head resistance introduced by an increase in the breadth of the strut makes an increase in strut dimension highly undesirable. Greater strength must, therefore, be obtained by a proper distribution of the material.

The effectiveness of the material in contributing to strength is determined by its distance from the axis of symmetry; and, assuming that failure is not due to crushing of the material, the effectiveness of any element varies as the square of its distance from the axis of symmetry. Here, again, the hollow steel strut seems to possess an advantage over the solid wood strut of the same weight. In the former, the material is removed to what is almost a maximum distance from the neutral axis (axis of symmetry), and is, so to speak, concentrated along the boundary of the section. In the solid wood strut the material is distributed throughout the section so that the distance from the neutral axis varies from zero to maximum for elements at the boundary. Consequently, the summation of the squares of the distances of each element *of the same weight* is not so great for the solid wood strut as for the hollow steel strut of the same total weight and section boundary.

This reasoning is based on the assumption that the ratio

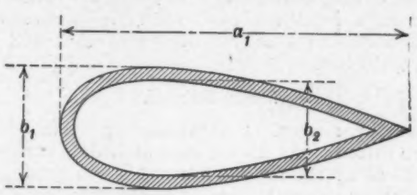


FIG. 2. HOLLOW STREAMLINE STRUT

of moduli of elasticity of the two materials is about the same as their density ratios, which is approximately true for steel and wood. In making the summation spoken of, we have, then, merely to multiply each element by the square of its distance, and, since the number of elements of the same weight in the two struts of the different materials is the same (the strut weights being equal), the conclusion drawn is valid.

A more detailed mathematical analysis of the same point follows. We will take any similar sections of solid and hollow columns, as shown in Figs. 1 and 2, where (1) is the section of a hollow steel column of the same weight and outside dimensions as the solid wood column (2).

Let E_1 be the modulus of elasticity of Fig. 1, E_2 that of Fig. 2, A_1 and A_2 their respective areas, and I_1 and I_2 their minimum moments of inertia assumed to be about the horizontal axis. By Euler's formula, the maximum loads that the two columns will sustain bear the following relation to their moduli of elasticity and moments of inertia:

$$\frac{P_1}{P_2} = \frac{E_1 I_1}{E_2 I_2}$$

Now, for steel and spruce $\frac{E_1}{E_2} = 20$, very nearly; and, also, their density ratio $\frac{r_1}{r_2} = 20$, very nearly.

Since the weights of the two struts are the same, their area ratio must be proportional to the reciprocal of the densities. Representing the external width of the struts by b_1 and the internal width of the hollow strut by b_2, when the internal and external sections of the hollow strut are similar, we have $\frac{A_1}{A_2} = \frac{b_1^2 b_2^2}{b_1^4}$. When the area of the solid strut is 20 times that of the hollow strut, $b_2 = 0.975\ b_1$. For similar sections the ratio of moments of inertia, $\frac{I_1}{I_2} = \frac{b_1^4 b_2^4}{b_1^4}$. Substituting the values obtained for b_2 in terms of b_1 and E_2 in terms of E_1, we have

$$\frac{P_1}{P_2} = \frac{E_1}{E_2}\left(1 - \left(\frac{b_2}{b_1}\right)^4\right) = 1.95.$$

From this it is seen that on the assumption of the applicability of Euler's law to hollow steel struts, such struts may

carry about twice the load of solid spruce struts of the same weight and section.

Buckling of Hollow Struts

Buckling, as will be shown, reduces the apparent superiority of steel over wood as a material for struts. Euler's column formula is based on the assumption that in bending no local indentation or buckling takes place. Such an assumption is, of course, entirely justifiable with respect to solid struts or even hollow struts having comparatively thick walls, but it is hardly valid for thin-walled columns, such as the steel struts under consideration. A limited strip in the wall of the strut considered as a "free body" is, in effect, also a small column loaded axially at each end. If we apply to this strip the laws that govern columns, we may expect such a strip to hold very little load. If the width of the strip is considerably greater than its thickness (and any other dimension ratio would hardly be justified in this discussion), it is obvious that its least moment of inertia must be low, especially at those places along the boundary where the curvature is low. The result of this comparatively low local column strength is that buckling takes place. Tests on plywood and steel struts with relatively thin shells have shown that failure does actually occur at those places midway between the ends of the strut where the bending stresses are high and the curvature of the boundary is low. In order to obtain the best results from steel-shell struts it is necessary, then, to provide some form of reinforcement that will minimize the tendency to buckle.

Shear Strength

Upon loading a strut so that bending takes place, shear stresses are introduced. In the case of hollow struts in which the material along the neutral surface is too limited in width or has low shear strength, these stresses may cause failure of the strut by shear.

The following equation, governing the intensity of longitudinal shear stress in a strut, shows how the shear stress varies with distance along the axis of the strut and at right angles to this axis.

$$S_s = \frac{dM}{dx I b} \int_{v_1}^{c} v\,dA$$

S_s = Intensity or unit shear stress along a line parallel to the axis of symmetry of the strut section and distant v_1 from the axis of symmetry, and in a direction parallel to the strut length. $\frac{dM}{dx}$ = Rate at which the external bending moment M changes with respect to distance x along the axis of the strut. I = Least moment of inertia of the strut section. b = Breadth of the section distant v_1 from the axis of symmetry. $\int_{v_1}^{c} v\,dA$ = First moment of the section bounded by a line parallel to the axis of symmetry and distant v_1 from the axis of symmetry, and the strut boundary, c being the distance from the axis of symmetry to the outermost fibre.

The elastic curve of a loaded strut of uniform section approximates a sine curve, so that the rate at which the moment increases with respect to distance along the strut is greatest at the ends of the strut where the slope of the elastic curve with respect to the straight line connecting the ends of the strut is greatest, and, consequently, the shear stresses are greatest at the ends of the strut.

The maximum value which the integral for the first moment attains is for $v_1 = 0$, so that with respect to distance at right angles to the plane of symmetry of the strut the maximum stresses occur in the plane of symmetry.

On the basis of the laws governing the strength of hollow columns such as interplane airplane struts, it would seem that hollow struts of the same weight and section boundary as solid spruce struts, and made either of wood having a high modulus of elasticity or of a steel shell, should give crippling loads superior to those of the solid spruce struts if reinforcement is provided to minimize buckling. Shear stresses in such struts are greatest at the ends of the strut in the plane of symmetry. Sufficient shear strength must be provided in hollow struts to prevent failure due to shear.

Book Reviews

AIRPLANE DESIGN AND CONSTRUCTION. By Ottorino Pomilio. (McGraw-Hill Book Company. 403 pp., 242 ill.)

This book covers a wide range and, being well and accurately written, it will be useful for the student as well as for the specialist or designer. The terminology is sometimes loose, and terms are introduced for which there is no very strong justification. Apart from these minor blemishes, the presentation is clear and sound.

Introductory chapters on the structure of the airplane are followed by some interesting notes on the radiator and engines, and on gasoline systems. Propeller theory is briefly dealt with.

Part II, dealing with the elements of aerodynamics, gives a simple introduction to the subject. It is feared that in the consideration of gliding flight and flight with power on, the introduction of logarithmic methods will make an easy subject seem somewhat harder than necessary.

A very interesting chapter deals with the possibilities of flight with an engine mantaining constant power at altitudes. There is also a novel study of long-range flying. The chapters on design contain many useful and handy tables. Stress diagrams are worked out with a graphical method for the bending moments in truss. There is also a short section on sand testing.

It is gratifying to see a book which is of real value in the aeronautical field.

AUTOMOBILE AND AERO ENGINES. By René Devillers. (Messrs. E. & N. Spon, Ltd., London.)

Problems are presented in a clear and simple manner which enables the novice to understand the solution readily, while the experienced designer can immediately locate formulæ and other data. While the author has at no time forgotten the possibility of practical application, the work is mainly concerned with fundamental principles and not with actual examples of construction.

Chapter III on thermodynamics, chapters IV and V on the mechanics, and chapters VI to XIII on design are especially good. Each chapter is a complete exposition of the subject under consideration.

The book is divided into the following chapters: 1. The working mixture. 2. The laws of gases. 3. The four-stroke cycle. 4. Inertia forces. 5. The engine turning moment. 6. Engine speed variations and flywheel design. 7. The cylinder. 8. The piston, piston rings and gudgeon pin. 9. The connecting rod. 10. Desaxé cylinders. 11. The crank shaft. 12. Valves on cam distributor gear. 13. Induction and exhaust passages. 14. Engine power and its variations. 15. The cooling system. 16. The crank case and lubricating system. 17. Speed regulation. 18. Engine starting. 19. The two-stroke engine. 20. The rotary engine. 21. The laws of similarity. 22. Engine testing. 23. Adaption of power available to power required. 24. Super-compression and super-charging engines. Appendix.

New Joint Board

The new Joint Army and Navy Aviation Board has held its first meeting with Secretary Baker.

Plans were discussed for the closer cooperation of the Army Air Service and the Naval Aviation Section, with a view to eliminating all duplication of work or expenditures, the discussion dealing largely with plans for the expenditure of the $25,000,000 appropriated for the Army Air Service and a like sum for the Navy.

Maj.-Gen. Charles T. Menoher, Director of Air Service, headed the Army section of the board, and Capt. T. T. Craven, Director of Naval Aviation, the Navy end. Secretaries Baker and Daniels were also present.

Michigan Airplane Factory

Incorporation papers of the Texas Aeroplane Manufacturing Company will be filed soon. The company will have a paid-up capital stock of $1,000,000, and its purpose is to construct and operate an airplane manufacturing plant at Grand Rapids, Mich. Lieut. C. G. Taylor, Lexington, Ky., is chief promoter of the project.

The Pacific as a Field of Aerial Activity

Now that the Atlantic has successfully been crossed by a flying boat, an airplane and an airship, and some of the difficulties involved in these exploits have been realized, attention is commanded by another great body of water, which has not yet been conquered by aircraft—the Pacific. A price of $50,000 has been offered by Thomas H. Ince to the first aviator who will cross the Pacific from America to Asia, as specified hereafter, and a seaplane, specially designed for the same purpose, is now building at the factory of the George D. White Co., at Los Angeles.

The Thomas H. Ince Prize

The "Rules and Regulations of the Thomas H. Ince Trans-Pacific Flight," states that the prize shall go to the aviator who shall first complete an aerial voyage across the Pacific Ocean, in a heavier-than-air machine, mechanically propelled, of any size and type. The flight may be attempted from either side of the ocean, but if westward the starting place must be from the Thomas H. Ince Aviation Field, at Venice, California, or the Thomas H. Ince Hydro-Airplane Station, at Venice, California, and the finish must be on the mainland of Australia, or the mainland of the Japanese group of islands or the mainland of the Philippine group of islands or the continent of Asia; if eastward, the mainland of the Japanese group of islands, or the mainland of the Philippine group of islands, or the continent of Asia, and the finish must be on the mainland of the United States of America. The course of the flight must be confined to latitudes 49 degrees, north and 32 degrees, 33 minutes, north, of the United States of America, and latitudes 41 degrees, 35 minutes, 20 seconds, north and 38 degrees, 45 minutes, south of the Eastern Pacific.

The contest shall be confined between the months of September, 1919, and February, 1920, inclusive, and contestants must complete the trans-Pacific flight within 288 hours from the time of starting.

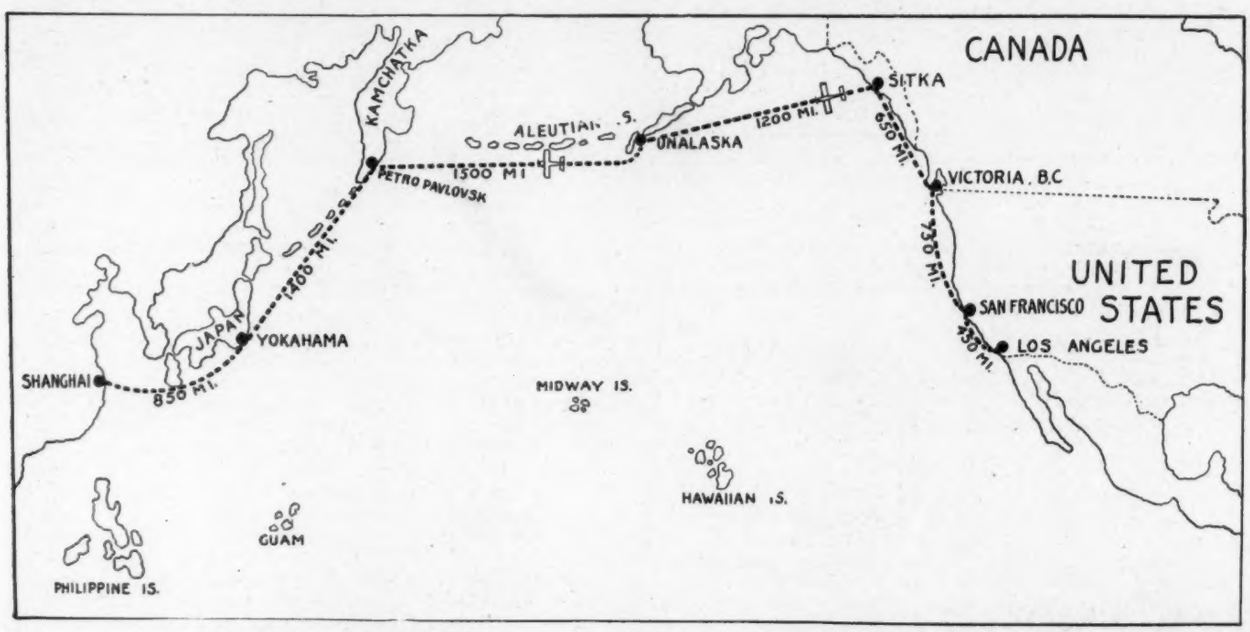
In the event that no contestant shall successfully complete the trans-Pacific flight, the contestant who shall have reached the Hawaiian Islands in the shortest length of time, shall be awarded the sum of $10,000; and in the event that no contestant shall complete a flight to the Hawaiian Islands, the contestant starting from these who shall fly the farthest in the direction of the Hawaiian Islands shall be awarded the sum of $5,000.

The contest is open to persons of any nationality holding an aviator's pilot license issued by any accredited aero club affiliated with the Fédération Aéronautique Internationale, or to persons so rated by any military or naval establishment.

The entry form, which must be accompanied by the entrance fee of $500, must be sent to the secretary of the Pacific Aero Club, Monadnock Building, San Francisco, at least fourteen days before the entrant makes his first attempt. No entrance fee will be required of any military or naval contestant.

All entrance fees will be applied toward payment of the expenses of the Pacific Aero Club in conducting the contest. Any balance not so expended will be refunded to the contestants pro rata.

The start of contestants may be made from land or water, but in the latter case, the contestants must cross the coast line at the beginning and end of flight. The time will be taken from the moment of leaving the land or crossing the coast line. All starts must be made under the supervision of an official of the Pacific Aero Club.



PROPOSED ROUTE ACROSS THE PACIFIC OF THE WHITE SEAPLANE

The White Hydro-Monoplane

This machine, which has been specially designed for the purpose of attempting to cross the Pacific, will be barred from competing for the Ince Prize unless the rules and regulations for the latter be modified to include the entire Pacific. The route which has been mapped out for the White seaplane skirts the American coast from Los Angeles to Alaska, whence it shapes its course by way of the Aleutian Islands and Kamchatka to Japan, with Shanghai, China, as its terminus. The route lies between 53 and 60 deg. latitude North, that is, entirely outside the belt specified in the Ince prize.

The distances to be covered on this route are as follows:

	Miles.
Los Angeles-San Francisco	450
San Francisco-Victoria, B. C.	750
Victoria, B. C.-Sitka, Alaska	650
Sitka, Alaska-Unalaska, A. I.	1,200
Unalaska, A. I.-Petropavlovsk, Kamchatka	1,500
Petropavlovsk-Yokohama, Japan	1,400
Yokohama-Shanghai, China	850
Total	6,800

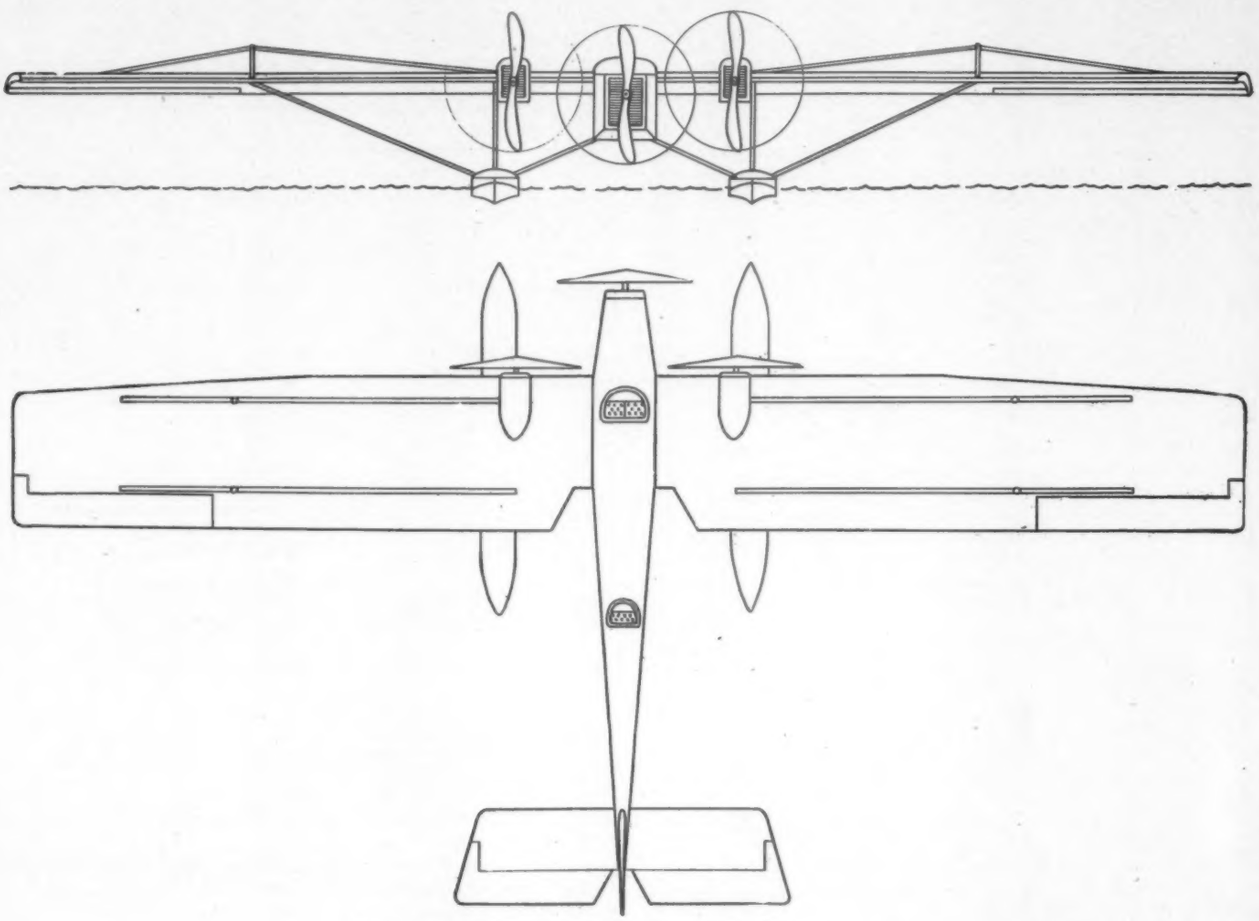
This route has been chosen in preference to one via Hawaii and other Pacific islands as being much safer owing to the fact that the longest non-stop flight measures only 1500 miles

and is generally in sight of land, whereas a flight from California to Hawaii involves a non-stop distance of over 3000 miles without any land being in sight between start and finish.

The White seaplane is a twin-float monoplane of original design. Its most striking feature is the disposition of the power plant, which is made up of a Hispano-Suiza 300 hp. engine installed in the nose of the fuselage and two 180 hp. engines of the same make which are mounted on the wings on either side of the fuselage. All three engines drive

The pontoons, which are spaced 15 ft. apart, extend more than half the length of the machine to prevent capsizing in a heavy sea. They are built of mahogany and cedar veneer, and are divided into numerous watertight compartments by means of bulkheads; each pontoon has sufficient displacement to alone support the machine afloat, and the fuselage is watertight. The height of the machine from the pontoon keels to the top of the fuselage is 9 ft.

The monoplane wings have an overall span of 82 ft. and



FRONT ELEVATION AND PLAN OF THE WHITE SEAPLANE

tractor airscrews. This fractioning of the power plant into three engine units, two of which develop a horsepower equivalent to the remaining unit is an interesting attempt to eliminate the drawbacks of mechanical breakdown in multi-engined airplanes, namely the decrease in flight speed and maneuverability where one wing engine fails. As this machine has been designed to normally fly with 300 hp., its designed speed then being 110 m.p.h., the chance of a forced landing due to engine failure is greatly lessened. On the trans-Pacific flight it is proposed to start off on the two wing engines, switch them off after a number of hours and turn on the central engine, and repeat the performance at given intervals to allow the engines to rest and to be inspected. Minor repairs and adjustments, such as relating to the carburetion and ignition systems, could therefore be made during the flight.

The fuselage is of monocoque construction, being built up of Haskelite, a veneer composed of Oregon spruce and African mahogany which is cemented together under hydraulic pressure. Two cockpits are provided in the fuselage, the one forward seating two pilots, while the after cockpit affords accommodation to the navigator. The fuselage is roomy enough to allow the pilot off watch to stretch himself, for which purpose a special locker is provided. The fuel and oil tanks are fitted in the fuselage between the two cockpits. The overall length is 39 ft.

are set at an angle of incidence of 4 deg.; they embody a sweepback and raked tips.

The wings are braced to the fuselage by means of solid struts, thus doing away with high-resistant external wire stays. This type of wing bracing has been thoroughly tested during the past two years on single-seater White monoplanes, not to speak of other machines, such as the Loening two-seater fighting monoplane, where is has proven its aerodynamical advantages and structural strength.

The control surfaces are balanced to facilitate manual control and comprise a divided elevator and rudder beside horizontal and vertical fins.

The weight of the machine empty is 3,700 lb. and fully loaded for the Pacific flight 7,900 lb. It is claimed by the manufacturer that this seaplane has, owing to the high efficiency of the monoplane wing arrangement and absence of external bracing wires, only 33 per cent the parasite resistance of a biplane of equivalent wing area, hence its great loading efficiency.

In view of the attention the Pacific seems to elicit as a coming scene of aerial competition it is interesting to note that with the exception of the Carribean Sea there is perhaps no part of the world which seems so well suited for sea flying services as the Pacific. Some valuable suggestions were made some time ago with regard to this subject by Capt. A. J.

Swinton (late R. E.) in an article contributed to the Engineering Supplement of the London *Times*, which is reproduced herewith in part.

Aerial Future of the Pacific

Distances in the Pacific are great and steamships are slow, while sailing schooners are slower still. There are points between many of which rapid transport would be a boon. The provision of *rapid, or even frequent* communication between them can never be provided except by airplane, because there is not sufficient commercial inducement to pay for the expense of providing it by any other means.

The meteorological conditions are good, the climate is warm and generous, and, though there are many violent storms in the Pacific, they are chiefly rather local in nature, not very long of duration, and, most important of all, while they can be clearly and unmistakably forecasted, they do not leave the surface of the ocean sullen and irritated for long periods after they have passed away, like the gales of the North Atlantic, which during the greater part of the winter is turbulent and stormy.

The geographical conditions are also nearly ideal, for every few hundred miles are to be found groups of islands forming sheltered spots where flying craft could take refuge or refill their fuel tanks.

Commercial Aspects

It will be asked, "Is there anything in it?" Though this question is almost impossible to answer, there are strong reasons for thinking that there is. The success of such a service would depend, primarily, upon the amount of transportation to be done, other conditions being satisfactory. It is better to consider mails and passengers apart, since it is likely that mails will be regularly carried by air before passengers.

The weight of mail matter, according to the annual report of the Postmaster-General, carried inwards and outwards between Great Britain and Australia and New Zealand for the last pre-war year was approximately 4,000 tons, rather more than half of which was outward from the United Kingdom and rather less than half was inward to the United Kingdom. Suppose, therefore, that Australia could be reached in five or six days either via Europe and the Malay Peninsula or via U. S. A. and Honolulu, and that the competing routes would share half the available traffic—that is to say, one half of the total traffic would be sent by one route and the other half by the other route—a maximum of about 2,000 tons per annum, total out and home, would possibly be available during the year along each route.

One must not assume, however, that the whole of the public who correspond with Australia and New Zealand would suddenly avail themselves of this new form of mail service; probably only one half of the mail—*i. e.*, that comprising newspapers, business letters, and samples—would at first be carried. Upon this the assumption is made that the mail to Great Britain via U. S. A. would be about 400 tons, while the mail in the reverse direction would be about 600 tons per annum.

American-Australian Mail

To this, however, must be added a proportion of the present mail between U. S. A. and our antipodean colonies. Though the exact figures for this are not available, it would appear from a perusal of the Postmaster-General's report to be not much less than 250 tons a year each way from and to America. If we allot 100 tons of this to the aerial route in each direction, we would have 500 tons from Australia and New Zealand to Great Britain and U. S. A. and 700 tons into the commonwealth via the Pacific.

This gives a working idea of how much mail matter would have to be carried—about fifteen tons per week from the United States, some ten tons per week to the States. To keep on the safe side, however, we will consider that there are only nine tons in each direction. To carry this, three flying boats, each capable of carrying three tons, in each direction would be required weekly.

Now the argument so far has been to show whether there would be any quantity of mails to carry; it seems a fair assumption that there would, and that passenger-carrying as a feature necessary to make the service pay can therefore be ignored—though, as a matter of interest, an indication of possible fares is given later.

The next question to consider is what would be the saving in time. This is shown in some comparative tables given below:

	Steam Ship	Sailing Schooner	Flying Boat	Time Saved
[1]London-Sydney	32 days	....	5 days	27 days
[1]Return	64 days	....	10 days	54 days
Sydney-Fiji	6 days	14 days	20–24 hours	5–13 days
Return	12 days	28 days	2 days	10–26 days
Sydney-San Francisco	19 days	....	2½–3 days	16 days
Return	38 days	....	5–6 days	31–32 days
Fiji-Samoa	3 days	10 days	6–7 hours	2½–9½ days
Return	6 days	20 days	12–14 hours	5–10 days
Samoa, Fiji, New Hebrides, Solomon Is. (subject to connections)	30 days	2 months	1 day	1–2 months
Return	2 months	4 months	2 days	2–4 months

[1] This is via Malay Peninsula, and though it does not strictly come within the scope of this scheme it is inserted by way of comparison

This table shows plainly that journeys "across country," hitherto almost commercially impossible on account of the time taken, can be speedily and comfortably carried out in a few hours, or at most in a few days. This fact has a distinct business significance.

Calculations in the question of airplane maintenance and running, based upon experience gained in pre-war days and modified by recent experience with machines built since the war, indicate that the all in cost of running a flying boat after the war, as a commercial proposition, should not exceed 1s. 6d. per mile—this figure including fuel, repairs, insurance, depreciation, pilots, office expense, and all maintenance charges. This would give the actual cost of flying a machine from Sydney to San Francisco as about £500.

Dividing the journey into stages, we can gain a rough approximation of the postal rates necessary to make a profit. Sydney, Brisbane, Mayborough, New Caledonia, New Hebrides and Fiji, 1½d. an ounce; islands between Fiji and Hawaii, 3d. an ounce; Hawaii and San Francisco, 4½d. an ounce. However, if the payment for letters and parcels between Sydney and San Francisco averaged only 2d. an ounce, and three tons were carried per trip, the receipts per trip would amount to £750.

Passenger Fares

As to passengers, with a maximum of about thirty and an average number of about twenty-five, the cost per passenger mile would average about three farthings to a penny a mile. The fare would depend, of course, largely upon the number of passengers; it might eventually be £20-£30 between Sydney and San Francisco.

Now that we have glanced at the preliminary financial features, let us recapitulate some of the possibilities resulting from the establishment of such a service.

First, the United States of America would be only some 2½ days from Australia, that is, a saving of nearly three weeks on the single journey. In addition to this, there would be a three times a week service; this would be a point of interest to the business men of U. S. A. and Australia. There are, however, others who would find out the advantages of such a service—namely, those who inhabit, or have to deal with, the coast towns and island groups along or near to the track of the flying boat.

The general line of the proposed service would be from Sydney to Fiji via Brisbane, Mayborough, the outliers of the New Caledonia group, and New Hebrides; thence via Samoa, Manahiki, Malden, Fanning and Palmyra Islands to Honolulu. From Honolulu to San Francisco the route would be pretty well direct unless a favorable wind is found to exist making it worth while to deviate from the straight path. This question of deviation to obtain favorable winds is one which has yet to be scientifically investigated, and need not be discussed here.

Refuges

Though the radius of action of a flying boat such as would be used on this service would be 500 to 600 miles, it is a necessary provision that a refuge of some kind should be provided every 200 miles or so, at which fuel and stores could be replenished, and shelter provided in bad weather. This necessity creates a tendency to locate the route from one island to the next, where such islands can be found at convenient in-

tervals. However, these islands do not always exist at the right places, and it is therefore necessary to supplement the natural resting and refilling points by artificial ones.

These would take the form of small depot ships of 150 to 200 tons, placed where wanted and kept in their position by astronomical observation. There would be a chain of them between Honolulu and San Francisco, while a few more would be required between Fanning Island and Honolulu, and possibly one or two in the Sydney-Fiji section. Their functions would be, firstly, to act as fuel depots for flying boats and to provide refreshments for passengers and pilots; secondly, to act as weather sentinels all along the route.

Climatic Conditions

The most important point in ocean flying is the weather. This is not because flying boats cannot fly in bad weather. They certainly can, and in point of fact they have been flying the North Sea by night and day in all kinds of weather for the last three years. It is far less the conditions of the air that matter than the condition of the sea. The depot ships would therefore have to keep an incessant meteorological lookout in order that pilots might be warned of the conditions expected some hours in advance.

It should be remembered that the flying machine is not yet so perfectly reliable that it is never forced to descend. When one of these forced descents has to be made it is always more comfortable for pilot and passengers and less exacting upon the machine if the surface of the sea is tolerably smooth. In short, to descend into the sea during a heavy storm will always be avoided if possible, until the day when the size of the machines makes them contemptuous of surface conditions.

These chains of look-outs along the route, each supplied with meteorological instruments and fitted with wireless telegraphy, should make an impossibility of such undesirable contingencies. When such unfavorable conditions happen to exist the pilot would simply wait till the "clouds rolled by," never a very long wait in the Pacific.

Business Features Summarized

Let us look once more at the business features of the proposition, which can be shortly summed up as follows:

Capital outlay for provision of landing-places, depots, stores, buildings, hangars, motor-launches, electric light plants, wireless apparatus, workshops, and all such charges can be put down at approximately £25 per mile of route.

As the length of the route is approximately 6,000 miles, the capital outlay for the "permanent way" would be, in round figures, £150,000.

The capital expenditure for the "rolling stock," or rather the "flying stock"—i. e., the machines—at about £8,000 each, assuming that four would be required to run the service and that another three would be kept in reserve, would amount to £56,000. This makes a total of £200,000, which, with an extra £44,000 as working capital, brings the total capital to £250,000.

The inclusive costs, as mentioned elsewhere, are taken at 1s. 6d. per mile flown.

From this it is simple to make a statement as to the possibilities of such a scheme maintaining itself.

An average charge of 2d. per ounce from Sydney to San Francisco would give the takings for one single trip, with a load of three tons, as £750 in round figures; the actual cost per trip would be approximately £500, leaving a net profit of nearly £200 per trip, or nearly £400 for each double trip.

There are 156 double trips in the year, giving a result of over £60,000 per annum, after paying for all maintenance and operating charges, repairs, and depreciation, and insurance.

So it will be seen that the aerial transport of mails over long sea routes may provide a means of communication which, while being cheap and speedy, has a reasonable chance of paying its own way.

Though this article has not dealt with the matter of inter-island and local services, there is a large scope for such services among certain groups. These local routes would be maintained by smaller boats carrying from eight to ten passengers, and costing from 9d. to 1s. per mile to run and maintain. Their capital cost would be about £4,000 apiece, while the cost of the permanent way would probably not exceed £15-£20 a mile.

Weather Reports Available

Civilian aviators contemplating long cross-country flights in any part of the United States may now wire Washington to find out what sort of weather they are likely to encounter, according to an announcement made by the Director of Air Service. This action is one of the first which implies recognition of the great part aviation is to play in commerce of the future.

"To assist aviators as far as possible to make their cross-country flights under favorable climatic conditions, subject to errors of a weather forecaster and without assuming any responsibility for accuracy, the meteorological officer of the information group, Air Service, U. S. A., will from the weather map reports and in consultation with the officials of the United States Weather Bureau attempt to forecast weather for flying in any part of the United States for thirty hours in advance of noon each day for the aviator making a request and stating points of intended flight," the announcement says.

"The result of this experiment may determine the value of an aerial meteorological service and warrant its organization as the cross-country flying increases and aircraft become more generally use for the transportation of passengers, mail and merchandise. Aviators making a flight following the prediction of the meteorological officer are requested to advise him as soon as possible of the accuracy of the report."

Commercial Aviation

A most interesting booklet entitled Commercial Aviation and Its Relation to the Community has just been issued by the United Aircraft Engineering Corp. of New York, for the purpose of acquainting the public with the present status of commercial aviation and its future possibilities.

Considerable space is given to airdrome construction and the illustrations of various types of landing fields are especially clear. Other pages are devoted to types of aircraft, speed, endurance, landing, load, altitude, safety, cost, cost of operation, performance, etc.

While it was originally intended that the distribution of these booklets would be very limited, it is now possible for all those interested in commercial aviation to secure a copy until the present supply is exhausted. Requests should be made to the Engineering Department of the United Aircraft Engineering Corp., 52 Vanderbilt Ave., New York.

Navy Sells Seaplanes

The sale of 265 Navy seaplanes has been authorized by Secretary Daniels, it was announced Aug. 2 by Acting Secretary of the Navy F. D. Roosevelt.

Mr. Roosevelt said that the sale of these machines will give commercial airplane transportation companies an opportunity to buy high-speed machines of large carrying capacity ready for immediate delivery. He said that a number of such routes are already in operation or contemplated in the near future, such as from New York to Atlantic City, San Pedro to Santa Catalina, Key West to Havana, Chicago to Milwaukee and other lake cities, and a projected route to the Bermuda Islands.

The sale will include 83 HS-2L pusher flying boats, each with a 330 hp. Liberty; also 72 H-16 and F-5 twin-tractor flying boats, each with two 330 hp. Liberty engines.

The Bureau of Supplies and Accounts, salvage and sale section, will issue complete schedules of the sale, giving the characteristics of all the machines to be sold, their location, appraised value, specifications and terms.

Balloon Base in New Jersey

A commission of Air Service officers recently inspected various tracts of lands in the vicinity of Lewistown, N. J., with a view to choosing a site for the central balloon and airship establishment the lighter-than-air branches of the Army and Navy Air Services propose jointly to create on the Atlantic seaboard.

The Naval Air Service has already settled on the location of a huge hangar for rigid airships near Lakehurst, N. J.; this will be 800 ft. long, 265 ft. wide and 174 ft. high, and hold either one 10,000,000 cu. ft. airship and two smaller ones, or two 5,000,000 cu. ft. vessels side by side. This airship station will be part of the proposed lighter-than-air establishment, which will cover several hundred acres of land, and include, beside smaller hangars and fields for Army airships, repair shops, gas plants and barracks; a school in which balloon students will be instructed in the operation of all types of lighter-than-air craft.

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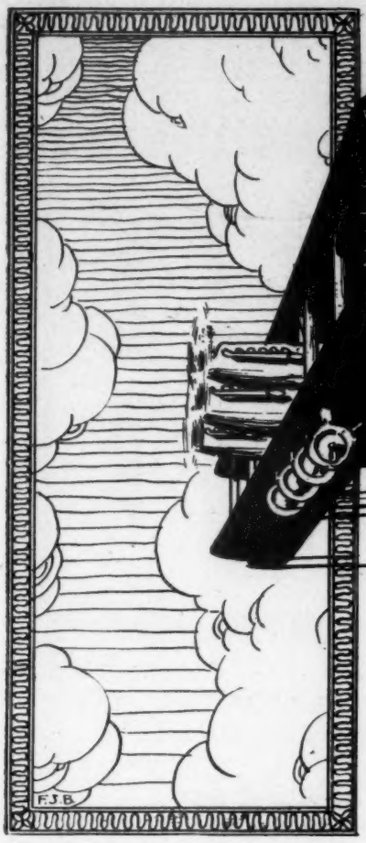

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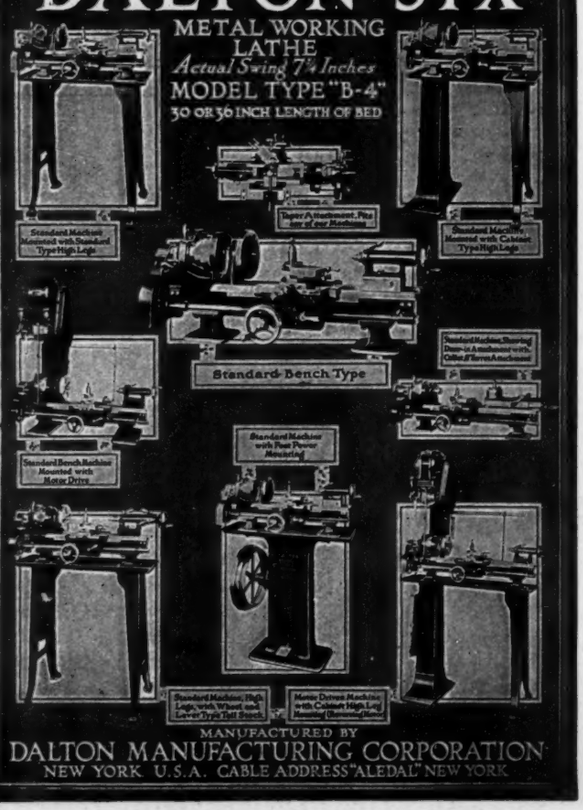

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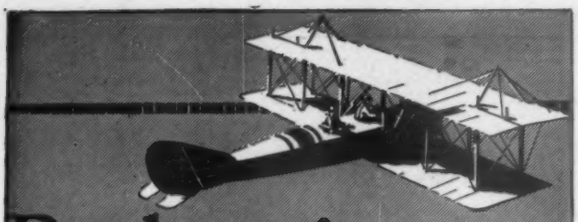

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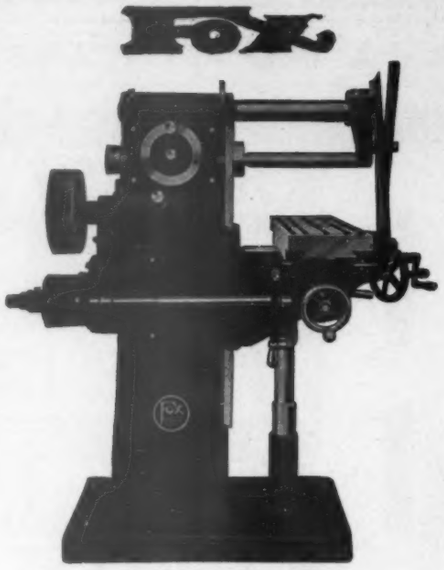

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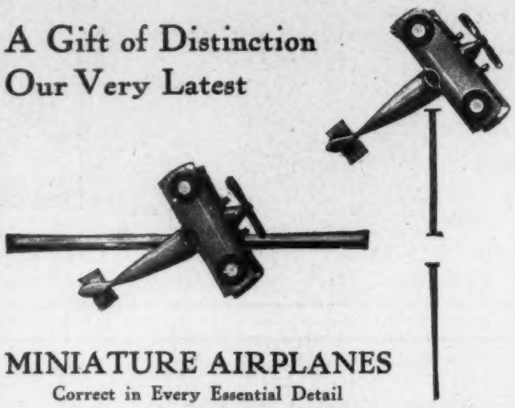

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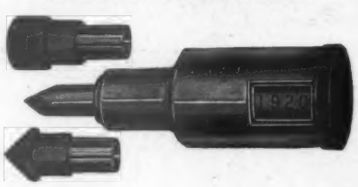

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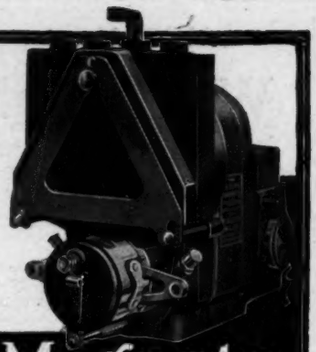

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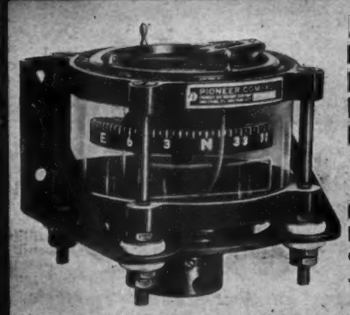

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